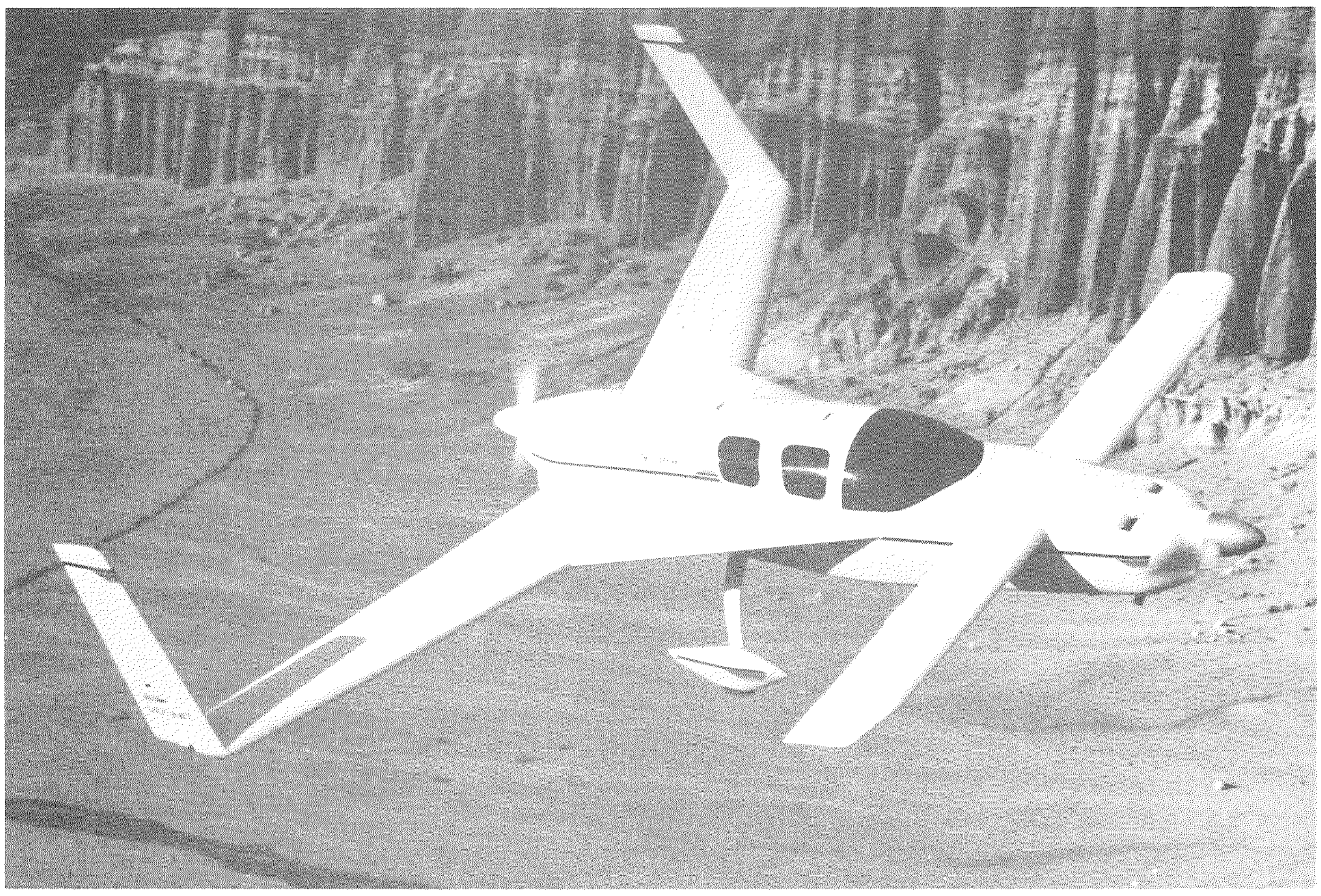
Defiant

SECTION II

0-320 AND 0-360

LYCOMING ENGINE INSTALLATION

FIRST EDITION



Be aware that these plans may be obsolete unless updated by "Canard Pusher," issue #49 through current.

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DEFIANT - SECTION II - ENGINE INSTALLATION

This set of plans is published for use as a guide to installing the engines on a homebuilt Defiant. There will be no attempt to educate the average homebuilder as far as the many, many details that a qualified A and P or AI mechanic knows and understands.

Due to the inherent complexity of a twin engine aircraft such as the Defiant, we believe it to be mandatory for the non A and P rated homebuilder, to obtain expert, professional assistance in the installation of the two aircraft engines, including wiring, control systems hookups, plumbing and cooling. This is especially important if you make the decision to install fuel injected engines, and or constant speed, feathering propeller . We believe that a number of builders will opt for these additionally complex systems. For this reason, we would like to state our position up front. RAF CANNOT PROVIDE BUILDER ASSISTANCE FOR THE INSTALLATION OF FUEL INJECTED AND/OR CONSTANT SPEED, FEATHERING PROPELLERS. We do not have the resources nor the expertise. Do not call or write to us for help in these areas. Seek professional expert help in this area. Rutan Aircraft does not encourage the use of any engine or installation component which would not be considered fit for service in a certificated aircraft. Specifically, engine service standards as defined by Avco Lycoming service manuals and bulletins should be complied with. Any Lycoming engine that is not fit for service in a Cessna, Piper or Beech aircraft, is not fit for service in a Defiant. This philosophy applies to the use of non-approved accessories such as carburetors or turbo chargers etc.

Each builder should complete the education he or she has begun in building his or her own aircraft by becoming as knowledgeable as possible about the engines he or she buys, flys and maintains. You can save yourself some big bucks, not to mention grief by learning all you can about these engines before you make the decision to buy. Very complete and informative maintainance and overhaul manuals are avialable at low cost from many aviation supply houses. Buy a copy of the applicable engine manuals covering your choice of engines and study them closely - you depend on your engines!

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WHICH MODEL ENGINE?

The Defiant is designed to accept 4 cylinder Lycoming aircraft engines ranging from a minimum of 150 hp to a maximum of 180 hp. Less than 150 hp will not give a sufficient margin of safety during single engine operation and the airframe is not structurally designed to handle any larger engines than the 4 cylinder 180 hp Lycoming. 6 clyinder engines are not approved.

Fred Keller's Defiant (N31999) uses two Lycoming 0-320, 150 hp engines. These are probably the most readily available and lowest cost engines and are also historically one of the most reliable engines ever built. Burt's prototype, N78RA, used Lycoming 0-320 160 hp engines for the first 900 hours of operation. These gave excellent, reliable performance with fixed pitch wood props. Recently Burt converted his Defiant to two Lycoming 0-360 180 hp engines with constant speed props. This combination makes the simple Defiant into a complex twin aircraft, requiring a current, proficient, multi-engine rated pilot.

Whichever engines you decide to use, good common sense dictates that if possible, they should be the same model. Commonality of parts, similar mounts, similar engine controls make for a simpler installation and easier maintainance. There are many engine models that could be used on a Defiant, some have conical mounts, some use dynafocal mounts. The pros and cons are as follows: Conical mounted engines have stiffer mounts and tend to feel a little harsher. On the other hand, they are usually cheaper and make a lighter installation. They are also generally more readily available. Dynafocal mounted engines have heavier, softer mounts and generally feel smoother. Since this design is only found on the newer engines, they are usually more expensive and harder to find. The type of mount cannot be changed and is a function of the way the engine crankcase is machined.

Some engines are designed and built specifically to operate fixed pitch props and cannot be made to operate hydraulic, controllable pitch props. Those that are built to operate constant speed props can also be made to use fixed pitch props.

All of these engines can be obtained normally aspirated with carburetors or with fuel injectors. Turbo charged engines are not approved.

The above is a very brief summary of the types of engines that will probably be used by the majority of Defiant builders. Even in this brief summary though, it can be seen that choosing the engines will require some thought and some research. We at RAF are not engine experts. We never have tried to develop propulsion systems. Our expertise lies in aerodynamics. You, the builder must decide on which engines you are going to use.

A few items to consider:
4 cylinders (6 cylinders are not approved).
Engine driven, mechanical fuel pump.
Magnetos - Slick or Bendix, your choice.
Alternator - or generator, 12 or 24 volt, your choice.
Starter - 12 or 24 volts, your choice.

Based on our experience over the past 12 years we recommend mid- time used engines over brand new or even new/rebuilt (zero time) engines. Mid-time engines are already broken in, therefore should not have any overheating problems. They are generally cheaper and in our experience, more reliable. It is difficult to break in new engines in a new, untried aircraft. New engines need to be broken in at high power settings. A new aircraft should have its envelope opened gradually and carefully. The two are not compatible.

WELDING UP YOUR OWN ENGINE MOUNT

The method we at RAF have used on almost all of the prototypes built here has been as follows: We hang the engine on an engine hoist in front of the firewall. Using a level, a plumb bob and a tape measure, we carefully position the engine at the proper height, with the appropriate down thrust and or side thrust as called out. We then cut pieces of 2 x 4 lumber and brace the engine firmly to the floor using Bondo, metal brackets bolted to rocker cover screws, etc, as required to "lock" the engines in space in front of or aft of the firewall, exactly where we want it to be. Of course, the fuselage must also be firmly located, using 2 x 4 lumber bolted through the wing attach hard points on the centersection spar and Bondo'd to the floor. We usually support the front of the airplane, under the forward firewall, on a saw horse with the nose wheel retracted. The fuselage must be level, longitudinally as well as laterally.

Now, bolt your dynafocal rings to each engine, or if you have conical engines, bolt the conical mounts in place on the engines as well as on to the firewall at the hardpoints called out in the drawings. Cut pieces of 4130N steel tubing to fit between the firewall and the engine. Be certain that the torsional braces (the 'X' tubes) do not interfere with the mechanical fuel pump, or the oil pan (Lycoming 0-360). One of the advantages of welding up the mounts in situ on the airframe, is just this, that you can be positive that there will be no engine or engine accessories to mount interferences.

Tack weld them into the positions called out. Be careful not to get the welded areas too hot, you cannot afford to overheat the firewall hard points, due to all the fiberglass and epoxy that makes up these hardpoints. At the same time you don't want to overheat the engine mounts or you could burn the rubber mounts themselves. This tack welding can be done either with gas welding equipment (oxy-acetylene) or better yet, you can use Tig (commonly known as Heli-arc) welding. Do not atempt to use electric arc welding (stick electrode) when welding aircraft grade steel tubing.

The trick here is to make short tack welds, about 1/4" long then stop and do the same at another point on the mount. This will allow the welds to cool, and will not get things too hot. In addition, it helps minimize warping.

When you have the mount completely tacked together, you can unbolt it from the firewall and from the engine and complete the welding job on the bench. If you are Tig welding, remember to stress relieve the weld clusters using oxy-acetylene equipment and a carburinzing flame, and allow it to cool as slowly as possible.

Clean the welded mount thoroughly and paint it with zinc chromate primer and finish it with a quality gas and oil resistant paint. We have used the heat resistant engine spray can paints available at any auto parts store, with good success.

We have used the above method to weld the engine mounts on at least 10 different aircraft with excellent success. The other choice is to build a heavy steel jig, one half of which represents the firewall. Spaced away the correct distance is the other half of the jig which is an accurate copy of the engine. The advantages of this method, shown in photos # 1 through # 8 are that you can go ahead and weld the entire mount without regard for overheating the rubber mounts or the firewall, and also that the weldment is firmly locked in position throughout the welding as well as the stress relieving process. The disadvantage is that it takes two accurately built, heavy duty steel jigs for a Defiant. Unless you plan on going into production, it is hard to justify for just one airplane.

If you are not a competent welder, you should get someone to help you who is, or you should take a welding course at a local trade school. Either method will give you perfectly acceptable engine mounts for your Defiant and you will get an education in welding into the bargain - isn't that what homebuilding is all about!!??

INSTALLING THE ENGINE MOUNTS

See Page F-2 of the accompanying blue printed drawings. The detail in the bottom left corner of this page shows how the engine mounts are structrually attached to the firewalls. This drawing is typical of all four attach points on the front engine mount as well as the rear engine mount.

You will have already done the 8 ply BID at 45° layup in each corner. This is the primary structure that will carry the engine mount loads. You will carefully layout the exact position of each bolt hole, using the W.L.s and B.L.s as shown on Pages F-1 and F-2. Drill these 8 holes with a 1/4" drill then using these 1/4" diameter holes as pilots, enlarge these 8 holes to 5/8" I.D. using a piloted spot facing tool or counterbore. It is a good idea when using a tool like this, to drill about halfway through from one side, then drill the rest of the way from the other side. This will give a nice clean 5/8" diameter hole. Now you will need to make up the EM-1 spacers. These are made from 2024-T3 Aluminum, and can be cut from heavy wall aluminum tubing, or machined from solid aluminum. The 0.6" length will vary slightly due to builder tolerances that can build up. Carefully measure the thickness of your firewall, including the glass layups both inside and outside the fuselage, at each engine mount point. Face the EM-1 spacers to be between .010" and .020", shorter than this measurement. This will ensure that when the engine mount bolts are tightened down hard onto the EM-1 spacers, the firewall and glass laminates will be properly "clamped" between the EM-2 blocks and the engine mount "flat washer". Temporarily install the EM-1s.

The EM-2 blocks are also shown on Page F-2, and they will be made from 2024-T3 aluminum 1/4" thick. They will be approximately the shapes shown, but should be filed to fit each corner, as tightly as possible. Hold these blocks into their respective corners and have a friend scribe the location of the 3/8" diameter hole with a long, thin scribe. Drill the 3/8" holes in all 8 blocks, then check the length of each bolt. You should be using AN6-37A bolts, but depending on your own builder tolerances, it is possible that you may require the next size longer.

Install the fiberfrax firewall material onto the plywood firewall bulkhead using RTV silicone. Install the .016 stainless steel firewall using a bead of RTV silicone, and transfer the 3/8" diameter bolt holes through the fiberfrax and stainless sheet. Now permanently install the 5/8" diameter EM-1 spacers with a generous coat of wet flox. The 1/4" thick EM-2 blocks should also be positioned in a bed of wet flox. Smear the AN-6 mount bolts with a light coat of grease, put an AN960-616 washer under the head of the bolt, and slip the bolts through the EM-2, EM-1 and welded engine mount. Install another AN960-616 washer and an MS21042-6 or equivalent self locking nut on each bolt. Torque these nuts to 300 inch/lbs.

You may find that your engine mount has warped slightly during the welding/normalizing process, and this may mean that you will have to "spring" the offending corner to get the bolt through. You should be able to easily "spring" as much as 1/4" of miss-match, but if it gets much more than 1/4" you may have to heat the tubing and bend it slightly. This is an acceptable practice and rather a normal situation.

After the flox cures, your engine mounts are firmly and permanently installed on each firewall. You may want to temporarily hang each engine so as to determine exactly where to place all of the items that are mounted on the firewall. This includes the gascolators, electric boost/fuel pumps, fuel flow transducer, intake air filters, batteries, starter solenoids, voltage regulators, cabin heat valve, etc. In addition, all engine control cables must be routed through the firewalls, so as to form a nice loop and to "point" right at the particular control lever (throttle arm, mixture arm etc) and these cables obviously must come through the firewalls clear of any of the above mentioned parts that will be mounted on the firewalls. The cables must have priority.

Once you have determined where every part must go, remove the engines, and mount all of the accessories on the firewalls by drilling through the firewalls and using AN3 bolts, AN960-10 washers, and MS21042-3 lock nuts. We usually drill a clearance hole through the firewall for each cable, that is large enough to slip the cable end through. This is normally a 3/8" diameter hole and will give some clearance on the cable itself. This clearance space should be filled with RTV silicone after the cable has been finally fitted and checked for correct travel and position.

Install the engine using the hardware and rubber engine mounts as shown on Page F-2. You will need an engine hoist, or a block and tackle from a strong rafter to raise the engine into position on the mounts. Be careful not to bash the engine accessories such as magnetos, vacumm pumps or mechanical fuel pumps as you work the engine into its mount. This is particularly true with the dynafocal type mount, where you will have to hook one magneto into the mount, then while raising or lowering the engine, hook the other magneto through the dynafocal ring.

As you fit the engine up to the mount, support the engine weight until you have all four bolts and nuts torqued up. Torque requirements are: For 3/8" x 24 bolts (conical mounts), 220 to 320 inch/lbs. For 7/16" x 24 bolts, (dynafocal mount), 430 to 580 inch/lbs.

COWLINGS

This set of plans contains enough information for you to manufacture your own cowlings. Frankly, for the best possible fit and shape, we highly recommend this procedure. Obviously, with all the prototype aircraft we have built over the past 10 years or so, this has been almost the only choice we have had, so we may be biased. However, we are certain that any prefabricated cowling, while it may fit resonably well, will never blend and fair into your own aircraft as well as one actually built on the aircraft.

It is best to have the spinners installed, or at least a 1/4" thick plywood disc, mounted in the same fore/aft position as your spinners will be. Refer to the full size patterns on Pages F-6 and F-7 and cut these out of 1" thick urethane foam. Wrap the engine in plastic and mount these foam "templates" at the appropriate fuselage station. Refer to the photos # 17 through #22 of Fred's installation. Fill in between these foam templates with 1" or even 2" thick urethane foam. Use Liquid X-40 two part "pour foam" or equivilant as a "glue" to glue these foam parts together as well as to fill in any gaps you may have. After the "pour foam" cures, you are ready to carve the shape of your cowling. Carve away until you are level with the pre-cut foam templates and until your foam "plug" fairs into the spinner.

step back and look carefully at your "sculpture". It should "look" good to you. It should fit well at the firewall and most of all, it should fair well into the fuselage. When you are absolutely happy with your "foam plug", see Page F-8 for the front cowling and Page F-10 for the rear cowling, layup 2 plies of BID at 45° in all the areas that require reinforcing. Trailing and leading edges, and the joint between the top and bottom cowl halves (for example). While this reinforcement layup is still wet, layup 4 plies of BID over the whole "foam plug" covering the reinforcement layups. Allow this layup to cure completely, (at least 24, better 48 hours).

Split the top and bottom cowling halves by cutting along the cowl seperation line as shown on Pages F-8 and F-10. Carefully read every note on these two pages to be sure you do not miss a step.

You will have to install four (4) stiffening ribs in the top half of the front cowl. These are made from 1/4" thick R-45 or H-45 PVC foam glassed on both sides with one ply of BID. Locate these ribs per the sketch on Page F-8. The front engine has up draft cooling, which requires two hot air outlets in the top half of the cowling. The layout and full scale cross section drawings (for these) are on Page F-8.

The rear cowling is much simpler, but the ram cooling scoop has to be made separately, then glassed onto the bottom half of the rear cowl. Note that the oil cooler is mounted onto a baffle in the rear end of the ram scoop. See page F-10. The only thing to watch for on the rear cowl is possible interference between the carb air inlet and the bottom cowl. If you are using Lycoming O-360 (180 hp) engines, you will have an interference here and should move the ram scoop closer to the B.L. 0 (centerline) of the lower cowl to allow enough room to clear the carb air intake (or build a large blister). We suggest you mount the rear cowl and check this interference before you attach the cooling air intake ram scoop to the bottom cowl.

Read all notes on Page F-10 for a clear understanding of what is going on. The rear engine air inlet ram scoop is deliberately spaced down from the cowling by 1" for lower drag. This "splitter" ensures that slower moving boundary layer air is not scooped in, and that only high speed "ram" air gets into the cowling for engine cooling.

Both cowlings can be installed using nut plates, flush washers and countersunk head screws (AN509) as shown in detail on Page F-8 or you can substitute camlocs, which although much more expensive allow quicker and easier cowling removal and installation.

EXHAUST SYSTEM

While it is of course quite possible to design and build a custom exhaust system to fit either engine on a Defiant, it is not neccessary. There are several exhaust systems that are readily adaptable to a Defiant. For the O-320, 150 hp or 160 hp, the best choice would be a stock Grumman Cheeta exhaust. With little or no modification, this exhaust will fit the front engine and will provide you with a source for carburetor heat as well as an excellent cabin heater in the form of a shroud around the muffler. This same exhaust system can also be adapted to the rear engine. This requires some cutting and welding, and since these exhaust systems are usually stainless steel, will require the use of a Tig welder.

The only problem with this "off the shelf" exhaust system fitting on the rear engine of the Defiant, is that the exhaust stack faces "forward" and must be cut and welded to face down and aft. The easiest method of doing this believe it or not, is to cut around the muffler at each end, rotate the muffler until the stack is appropriately positioned, then reweld both ends of the muffler. This method has been used successfully and amazingly took less than an hour to complete. The other less desirable choice would be to cut the stack off close to the muffler. Cut at about a 45° angle, rotate the stack and weld it back together, with the stack now facing aft.

For the O-320, 180 hp engines, the Grumman Tiger, AA-5B exhaust system is probably the best choice and can be adapted exactly as described for the O-320 installation. For Burt's Defiant, we adapted a set of Beech Duchess exhaust systems simply because we had them available. The front engine required essentially no modification. The rear engine had to have the stack rotated to face aft. As a result, N78RA has excellent cabin heat from a shroud wrapped around the front muffler, and the original carb heat is used front and rear.

There are several other standard, readily available exhaust systems that could be adapted. Keep in mind that you should look for airplanes with shallow cowlings such as found on most twins like the Duchess, or like the Grumman single engine models. This assures that the exhaust system will be short or tight enough (vertically) to fit in the cowling. As an example, the exhaust system from a Cessna 172 or 177 can be made to work but it must be shortened by cutting a section out of each exhaust pipe, between the engine flange and the muffler and rewelding them to get the muffler up close enough to the engine to fit into the Defiant cowling.

Although a standard off the shelf, certified exhaust system can be quite expensive, it is still the best choice. Since it will provide you with a design known to work, it gives you a reasonably quiet system due to the muffler, it gives you a source of heat for carb heat as well as cabin heat, and since it is stainless steel should give a reasonable service life. Home made exhaust systems can be a real source of problems. Burt went through half a dozen on the VariEze before coming up one that would last!

FUEL SYSTEM

The Defiant has two main fuel tanks (each approximately 50 gallons), and two 4 gallon sump tanks. The fuel from a main tank feeds into its sump tank and then to an engine. The two fuel valves, termed ENGINE VALVES (not tank valves), are used to control fuel. Normally, the left fuel tank feeds the front engine and the right fuel tank feeds the rear engine. This can be modified by the pilot, either engine can be crossfed or shut off (fire emergency or maintainance). It is impossible for either engine to obtain fuel simltaneously from both tanks. See your Defiant Owner's Manual for more detailed information, including a fuel system schematic.

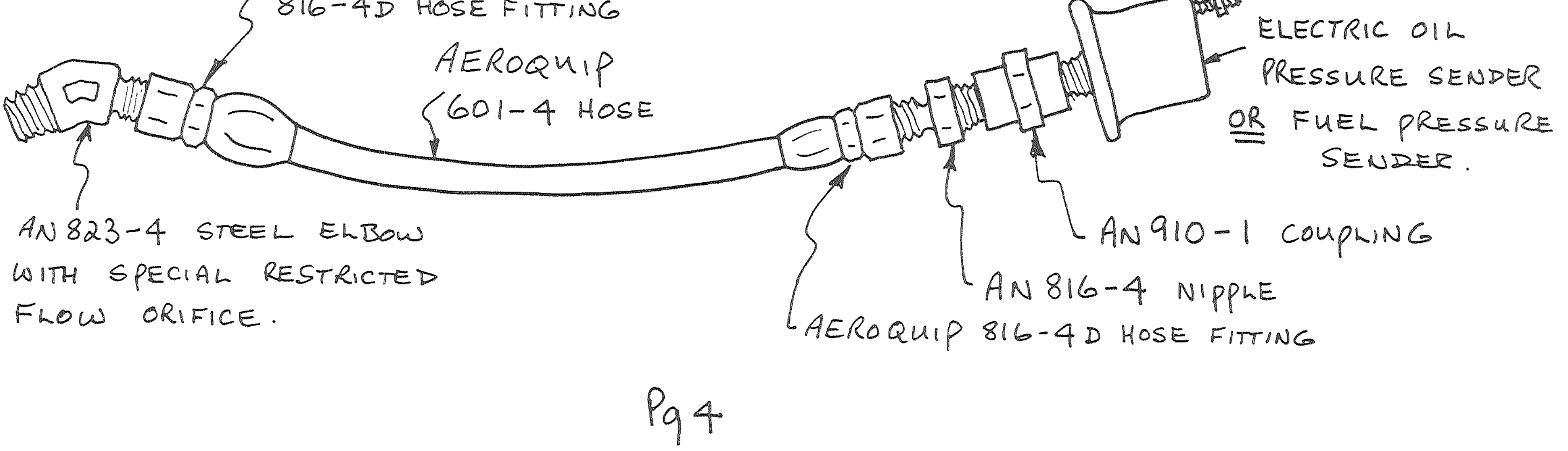
You will plumb your fuel system, from the forward valve to the forward firewall, and from the aft valve to the aft firewall, using 3/8" diameter aluminum tubing. At each firewall, you should use a bulkhead fitting, such as an AN833-6 , to pass the fuel line through the firewalls. From this fitting on the engine side of each firewall, you should hard plumb a 3/8 stainless steel fuel line to the gascolator (be sure to get the "fuel in" and "fuel out" correct). From the gascolator you will hard plumb to the electric boost pump. These pumps can be the simple solid state 'Facet' electronic fuel pumps (available 12 volts or 24 volts) or the more complex Bendix type (with contact points).

The electric fuel pumps should be mounted on the firewalls. From the electric fuel pumps to the engine driven, mechanical fuel pumps (on the engine accessory case), you must use an approved aircraft grade flexible fuel line, such as Aeroquip 601, stainless steel braided hose or similar. Good practice would demand that these hoses were further protected by aeroquip fire sleeve. Use Aeroquip 601 hose from the outlet on the engine driven mechanical fuel pump to the optional fuel flow transducer which should be mounted on the firewall. Again, flexible Aeroquip 601 hose should be used to connect the fuel flow transducer to the carburetor. If you elect to not have fuel flow information, you should plumb directly from the engine driven mechanical fuel pump to the carburetor. We prefer to use flexible Aeroquip 601 hose for this connection as well. If you install a fuel pressure gauge you can install a 'T' in the flexible fuel line between the mechanical fuel pump and the carburetor. A direct reading fuel pressure gauge (capillary) or an electice fuel pressure gauge can be used.

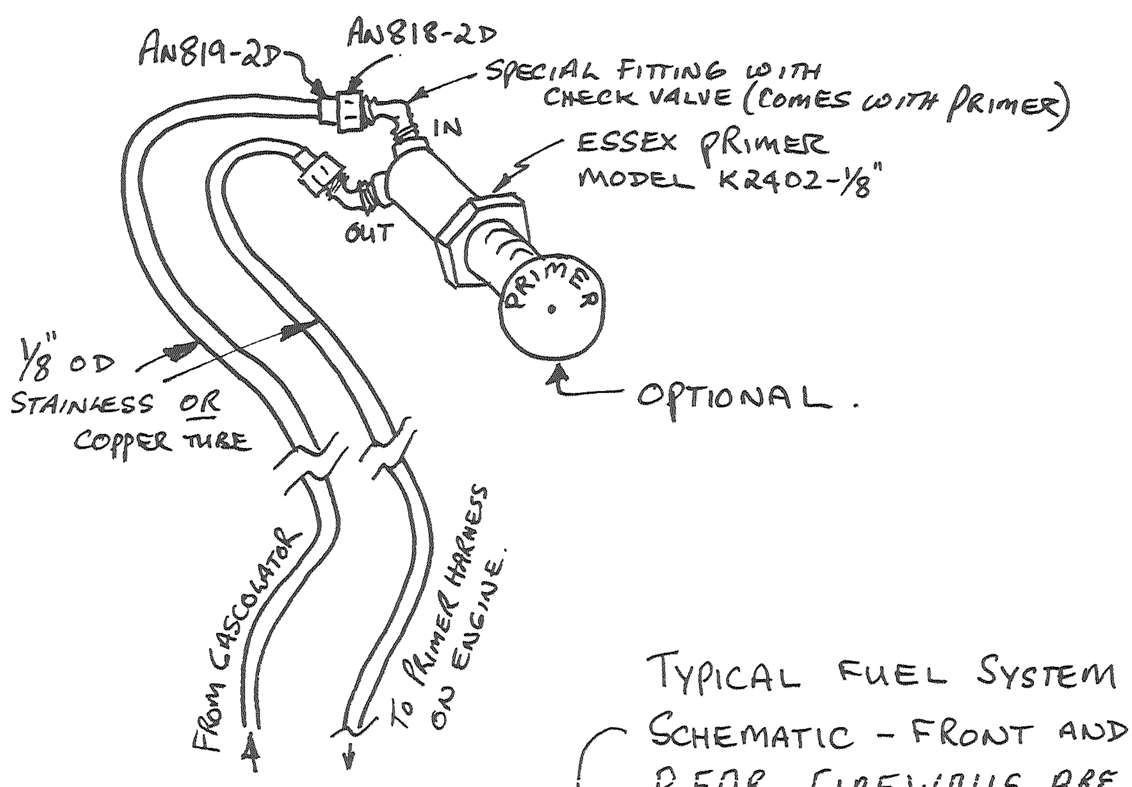
If you elect to use a manual primer, the primers themselves should be mounted on the instrument panel conveniently placed for use in the engine starting sequence. A fuel line must be run from the top of each gascolator, through the firewall to the primer on the panel. A second fuel line must run from the primer, through the firewall (bulkhead fitting) to the engine. The engine must be equipped with a stainless steel primer "harness" feeding at least 3 cylinders. This is normally a Lycoming accessory, and will have special injector nozzles which screw into each cylinder, from which the fuel is sprayed into each cylinder at the inlet valve.

See the accompanying sketches for details and part numbers. These show systems we have used successfully on several installations over the past 12 years. Obviously as an experimenter, you can design your own system or modify the fuel system shown, but for your own safety, get professional advice on whatever you design or change. RAF can only support you if you use the system shown.

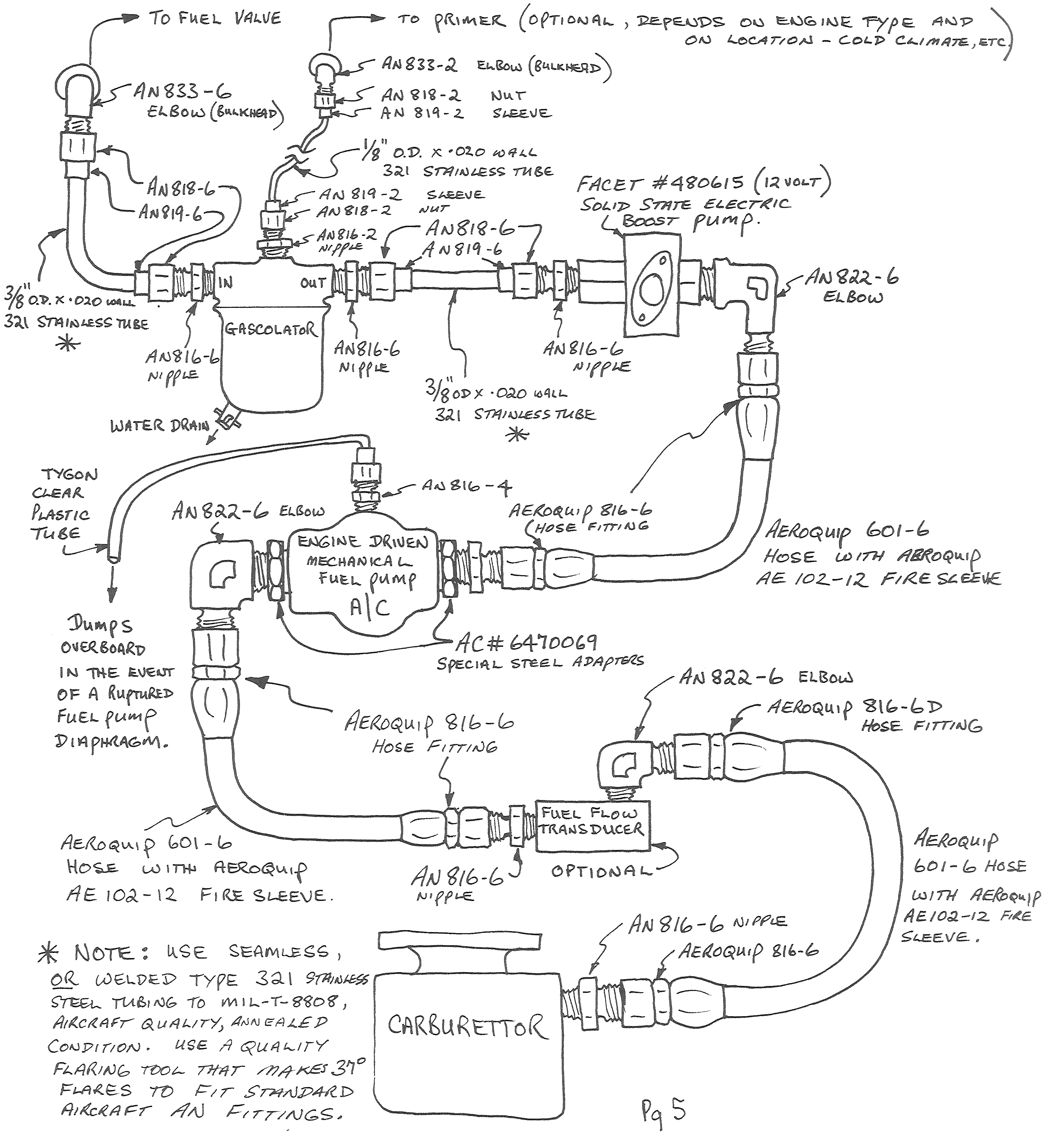
TYPICAL METHOD OF INSULATING ELECTRIC FUEL OR OIL PRESSURE SENDERS FROM VIBRATING ENGINE


AEROQUIP 816-4D HOSE FITTING
AEROQUIP 601-4 HOSE
ELECTRIC OIL PRESSURE SENDER OR FUEL PRESSURE SENDER.
AN 823-4 STEEL ELBOW WITH SPECIAL RESTRICTED FLOW ORIFICE.
AN 910-1 COUPLING
AN 816-4 NIPPLE
AEROQUIP 816-4D HOSE FITTING

OPTIONAL PRIMER PUMP SCHEMATIC.


AN819-2D
AN818-2D
SPECIAL FITTING WITH CHECK VALVE (COMES WITH PRIMER)
IN
ESSEX PRIMER MODEL K2402-1/8"
OUT
PRIMER
OPTIONAL.
1/8" OD STAINLESS OR COPPER TUBE
FROM GASCOLATOR
TO PRIMER HARNESS ON ENGINE.

TYPICAL FUEL SYSTEM SCHEMATIC - FRONT AND REAR FIREWALLS ARE SIMILAR


TO FUEL VALVE
TO PRIMER (OPTIONAL, DEPENDS ON ENGINE TYPE AND ON LOCATION - COLD CLIMATE, ETC)
AN833-2 ELBOW (BULKHEAD)
AN 818-2 NUT
AN 819-2 SLEEVE
AN833-6 ELBOW (BULKHEAD)
1/8" O.D. x .020 WALL 321 STAINLESS TUBE
AN818-6
AN819-6
AN 819-2 SLEEVE
AN818-2 NUT
AN816-2 NIPPLE
AN818-6
AN819-6
FACET #480615 (12 VOLT) SOLID STATE ELECTRIC BOOST PUMP.
AN822-6 ELBOW
3/8" O.D. x .020 WALL 321 STAINLESS TUBE *
IN
OUT
GASCOLATOR
AN816-6 NIPPLE
AN816-6 NIPPLE
AN816-6 NIPPLE
3/8" OD x .020 WALL 321 STAINLESS TUBE *
WATER DRAIN
TYGON CLEAR PLASTIC TUBE
AN816-4
AN822-6 ELBOW
ENGINE DRIVEN MECHANICAL FUEL PUMP
A/C
AEROQUIP 816-6 HOSE FITTING
AEROQUIP 601-6 HOSE WITH AEROQUIP AE 102-12 FIRE SLEEVE
DUMPS OVERBOARD IN THE EVENT OF A RUPTURED FUEL PUMP DIAPHRAGM.
AC# 6470069 SPECIAL STEEL ADAPTERS
AN 822-6 ELBOW
AEROQUIP 816-6D HOSE FITTING
AEROQUIP 816-6 HOSE FITTING
FUEL FLOW TRANSDUCER
OPTIONAL
AN816-6 NIPPLE
AEROQUIP 601-6 HOSE WITH AEROQUIP AE 102-12 FIRE SLEEVE.
AEROQUIP 601-6 HOSE WITH AEROQUIP AE102-12 FIRE SLEEVE.
AN816-6 NIPPLE
AEROQUIP 816-6
CARBURETTOR

* NOTE: USE SEAMLESS, OR WELDED TYPE 321 STAINLESS STEEL TUBING TO MIL-T-8808, AIRCRAFT QUALITY, ANNEALED CONDITION. USE A QUALITY FLARING TOOL THAT MAKES 37° FLARES TO FIT STANDARD AIRCRAFT AN FITTINGS.

ENGINE BAFFLING

Full scale drawings or patterns of every piece of baffling required for the front engine as well as the rear engine are shown on Pages F-11, F-12, F-13 and F-14. The recommended materials for the aluminum baffles is 6061-T4 and we recommend using it in a thickness of .040". This may be a little heavier than what some would use, however, we have found it to give the longest life. Do not use 2024-T3 or T4 aluminum for baffling, it is too hard and will crack. This material is commonly available from both of the RAF approved material suppliers.

The procedure outlined below assumes that you have already built and installed your cowlings, including all screws and or camlocs.

The best way to transfer these patterns to the aluminum we have found it to use typing carbon paper. Lay it directly on the aluminum and using a straight edge and a french curve, carefully trace over all the relevant outlines. A used up ball point pen does a fine job. Press firmly, and be sure to go over every relevant line. The result will be a nice clear full size black outline and you will still have your original. The other choice is to trace the original onto a stiff paper such as manila paper, cut this out with scissors, mount the paper templates on the engine, trim to fit as required, then trace around the corrected manila paper template onto the aluminum. The third and worst choice is to cut up the originals and glue them onto the aluminum.

You will need a few pairs of good quality tin snips. We like the offset snips such as Lever Snips or the Weiss aircraft snips. In either case, you should get at least a pair to cut to the left and a pair to cut to the right. A pair to cut straight ahead is also nice to have, but not essential. A "nibbler" tool is also very useful.

One other thing to bear in mind, although it really should not be a problem, and that is that these full size drawings were run on a blue print machine which does not give an absolutely exact copy size for size. There can be a small error in one direction or the other, depending on which way it was run through the blue print machine. This error was zero from top to bottom and as much as 0.1" from side to side on the sheets we checked. This means that the baffles are actually shown a little larger than full scale from left to right. In fact this should not cause any noticable problems.

The procedure then is to cut out all of the aluminum baffles and assemble them together and onto the engine as required. You may have to make small adjustments to suit your engine. (Keep in mind, that these particular templates were drawn from actual templates used on Lycoming 0-320 engines - 0-360 engines have cylinder barrels approximately 0.6" longer than 0-320 engines, so you will have to adust for this difference if you install 0-360 engines).

Install all of the aluminum baffles onto the engines. Now try one half of the cowling on at a time. Install all screws or camlocs around the firewall to position the cowling correctly. You probably will have some interferences. Scribe the aluminum baffles, and trim them to give you between 0.3" and 0.4" clearance between the edge of the aluminum and the cowling all around. (See detail on Page F-11).

Install neoprene/asbestos flexible seals (available 40" wide, on a roll - this material is not cheap, approximately \$6.50 per ft^2, so layout your strips carefully, onto the aluminum baffles so as to lap onto the cowling about 1 1/2" as shown in the detail on Page F-11. Be certain that you install these seals on the proper side of the aluminum. You are trying to seal up the baffles to force the high pressure cooling air to go only through the cylinder and cylinder head fins. Of course you will have to have cooling air pass through the oil coolers as well. Other than that, if the high pressure air can leak anywhere else, it will hurt your cooling. Obviously you cannot make an absolutely perfect seal, but you must do the best you can. The neoprene/asbestos seals are normally installed with pop rivets spaced about 1" apart. An aluminum strip under the heads of the rivets, will help to hold the flexible neoprene/asbestos material in place. Judicious use of RTV silicone (we prefer clear, but silver or red are good) will help get virtually every leak sealed up. The RTV silicone can be applied directly to the cooling fins (if they are clean) and it will stick very well, and will not be affected by the heat.

A good idea is to spend a little time at your local airport, looking inside the cowlings of as many different airplanes as you can, to see exactly how the various factories did their baffling jobs. Pay close attention to how they fitted and attached aluminum baffles to the engines, around starters and alternators and how the mag wires were routed through the baffles (we like the overlapping plastic engine baffle ignition wire seals, part #524, Aircraft Spruce). Ask questions of the A and P mechanics who may be working on an engine. Check with your local EAA chapter, talk with the EAA designee or any builder who has done a successful engine installation on a homebuilt such as a VariEze or a Long-EZ. An excellent book on the subject is Tony Bengilis' "Firewall Forward". Tony writes the excellent "Sportplane Builder" articles published each month in EAA's Sport Aviation magazine. You can order Firewall Forward from Tony Bingelis, 8509 Greenflint Lane, Austin, Texas 78759.

ENGINE CONTROL SYSTEMS

This is one of the more critical areas from a flight safety stand point, and again, we cannot call out exact details of how this should be done due to the wide variety of engine types that can be used on a Defiant and due to the wide variety of builder experience. We suggest you spend some time looking at engine controls on as many factory built, as well as homebuilt aircraft as you can. Use only high quality push pull control cables. Aircraft Spruce can make up this type of cable in any length to order.

You will have to carefully measure the length of each cable required for your aircraft, throttle, mixture, carb heat and prop governor control (if required). Each will be a different length, depending on which engine, carburetor (horizontal or vertical) fuel injector, etc you have. NOTE: The outer cable of each control cable must be securely anchored to a bracket, which must be mounted on the engine. Do not try to anchor the outer cable to the engine mount or firewall. It must be mounted so it vibrates with the engine. Enough of a loop must be allowed for the expected vibration of the engine in its rubber mounts. This is a difficult thing to describe, and an easy one to grasp if you can actually see one correctly installed. If you have any doubts about your ability to safely and securely hook up the critical engine controls, have it done by a person who is qualified and familiar with the requirements for this job.

Some cables are anchored with clamp plates, others with 'U' bolts. Whichever you use, this must be absolutely secure, and not able to slip and change the control authority the pilot has over his or her engine. There is nothing more frustrating than having a perfectly good engine, that you cannot use due to a control cable attachment failure. It happens from time to time and can cause a serious problem. Be very careful and conciencious in this area.

Once all of your control cables are hooked up, check the travel of each control very carefully, and adjust as required to give full and complete throw of each, be it throttle, mixture, carb heat or prop governor control. Each must be observed to move freely from one stop to the other. This check will require two people. After all adjustments have been made be sure to tighten the jamb nuts that secure the spherical rod end bearings onto the ends of the push/pull control cables at both ends (in the cockpit and in each cowling). See Page F-1 for sketches shown in the most commonly used control cable ends and atach methods.

N78RA the original prototype Defiant, uses conventional vernier controls for the mixtures and the props. These are standard aircraft type push/pull controls, normally found on single engine aircraft. The ones with large plastic knobs with a button in the end of the knob that allows rapid movement of the control, if the button is depressed, or a vernier screw movement, without the button depressed.

This gives very fine control fidelity, but certainly is unconventional for a twin engine aircraft. It takes some getting used to, but now that we have a few hours in the airplane, and have gotten accustomed to it, we get along fine with it.

We are not advocating the use of this type of control, we only mention it because that is what we have used and it works quite well. N78RA has "plans built" throttles, which use standard aircraft type push/pull cables with rod end bearings.

Most builders will probably elect to use the more conventional throttle, mixture and prop handles, all in a row, as shown in the plans. Carb heat controls can be conventional "choke cable" type, which is what we use in N78RA and which work well.

At the risk of repeating ourselves, we cannot over emphazise the importance of careful, good workmanship in this area of critical engine control. Use good judgement and when you are done to your satisfaction, have another builder, or a professional A and P mechanic look at your work. This last suggestion is highly recommended for all of your work on your Defiant. Many times you will find that a fresh pair of eyes will see some quite obvious little thing, that you may have been looking at for weeks, but not seeing - it is a question of not seeing the trees for forest. A second opinion could save hours of unneccessary repair and or embarrasment.

ELECTRICAL WIRING

A detailed wiring schematic is shown on Page F-5 and this system is exactly what Fred Keller used on his Defiant and is also essentially the same as Burt used on his prototype, N78RA. The parts list presented on Page F-5, lists exactly what Fred used. Of course you do not have to use the same engine instruments, landing light etc, as Fred used, these are merely presented as a guide.

A simplified schematic of this wiring diagram is also presented in the Defiant Owner's Manual on Page 10. Note that, unlike other twins, the Defiant uses two completely redundant electrical systems with two batteries. This allows a short run for the heavy cable required from battery to starter. If a battery is run down, it can be charged by the other system via the buss tie switch. Full alternator charge capability is thus available to recharge the other system. However, the buss tie is not adequate for the current requirements for engine start.

The buss tie is also useful to backup many electrical system failures. For example, if the front alternator fails, it can be shut off and the buss tie engaged so the rear alternator can charge both batteries and allow use of all components on both the front and rear buss. If a battery fault exists the battery can be removed by turning off its master switch. The buss tie can then be engaged to supply power to all components from the other system. Note the sharing of critical components on front and aft systems, i.e. if two coms are used, one is on the front system and one is on the aft system. The pilot has displays of the alternator output and voltage of each system, as well as buss tie current, so he can completely access the condition of the entire system. The pilot should study the diagram thoroughly in order to be prepared to correctly handle electrical system failures.

Wire sizes are called out for a 12 volt system (a 24 volt system would use wire sizes half of what is shown for 12 volt). It is recommended that aircraft quality stranded wire (not solid wire as used in automobiles) be used throughout. Ring terminal ends (not spade terminals) properly crimped, using the correct terminal ends, and the correct tool should be used rather than soldering. Soldered joints tend to fatigue and break with time in the vibration prone environment of an aircraft.

The 60 amp diodes shown, must be used to prevent a shorted alternator from shutting down the whole system. Fred used automotive type 60 amp diodes.

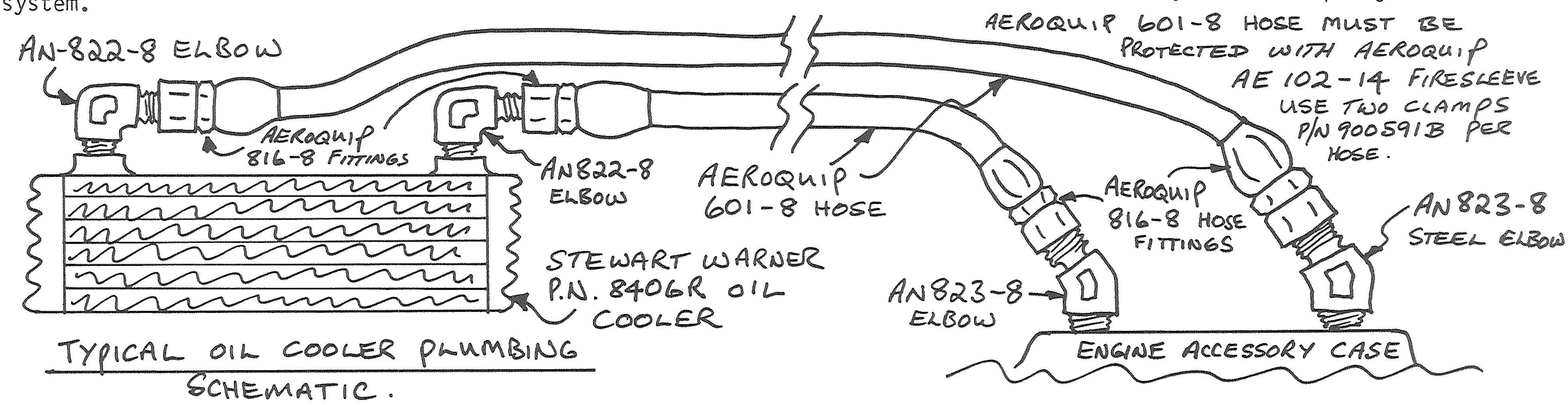
If you are not familiar with electrical wiring, particularly aircraft wiring, get expert help. Check at your local EAA chapter or airport for someone who can at least check your work. There is no substitute for perfect work when wiring up your Defiant. It must be absolutely correct before you attempt to fly it.

ELECTRICAL PITCH TRIM

The electric pitch trim system shown on Page F-4 is exactly what Fred built and installed in his Defiant. Fred used a trim servo gear motor from a Piper, Model PET-1 (6582104) which can be obtained quite cheaply from a local aircraft salvage yard. The system shown can be installed into a homebuilt Defiant even after it has been completed, including paint, without any problem. Clamp PT-1 clamp to C27 (Section I, Page 27) and the belcrank arm, PT-2 is bolted to this clamp. Two C-43 Century springs are attached to the ends of PT-2. A suitable length of 1/4" pitch #25 chain (start with 16") is hooked to these two springs, and is run around a small (10 tooth) sprocket, which is run by the Piper trim motor. After you have the whole system set up, you may find you have to shorten the chain a little to obtain the desired pitch trim authority. Watch out for the top run of the chain falling onto the bottom run, and becoming fouled with the sprocket as you run to full nose up trim.

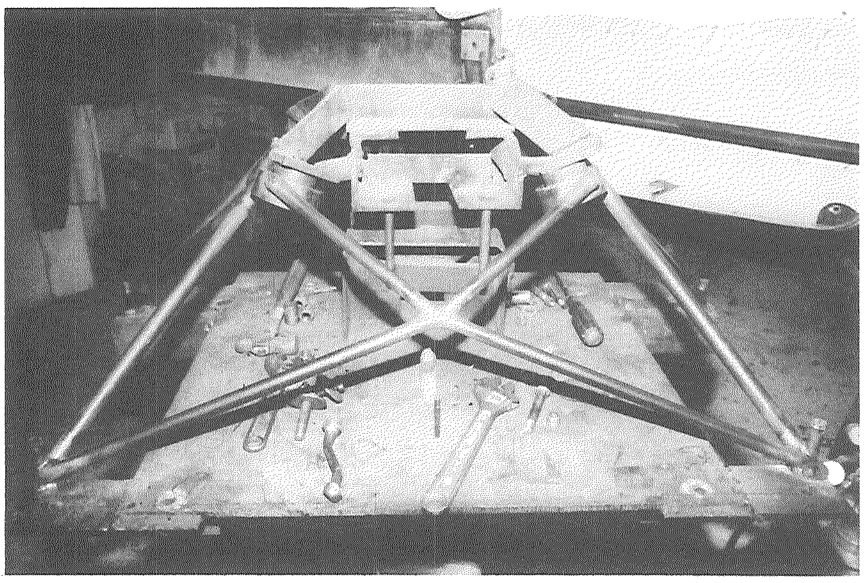
This trim system works well in Fred's Defiant - trim rate is quick, but very controllable. Use of this "bungee" type trim system allows "hands off" flying in pitch. The Defiants strong longitudinal stability makes it a very stable platform and she will hold any set trim speed as long as you want, or at least as long as you have fuel!

The pitch trim spring authority should be adjusted to provide 13 lbs of aft stick force at the full nose up trim position and 6 lbs of stick force at the full nose down trim position. Forces are measured using a spring scale at the center of the stick, with the stick held at the neutral elevator position. Set this on the ground, prior to first flight by adjusting the length of the chain, and or the length of the springs.

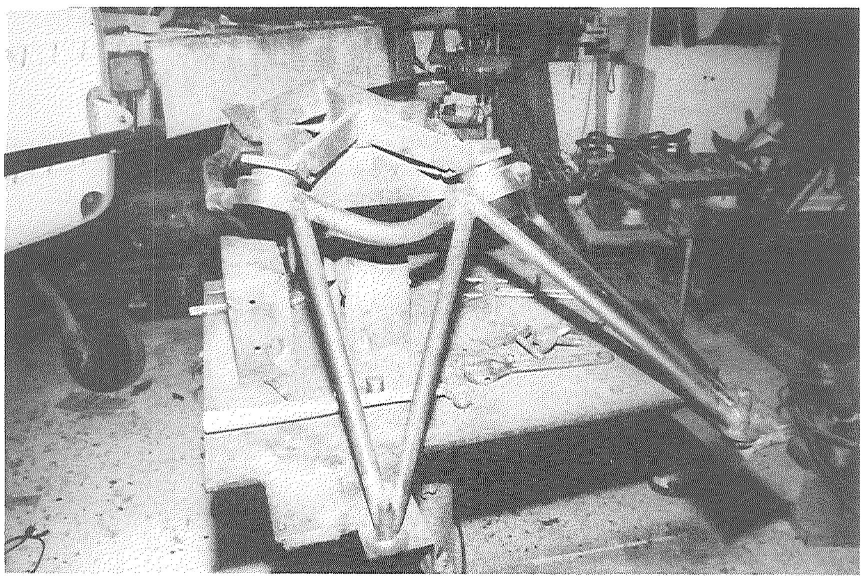

AN-822-8 ELBOW
AEROQUIP 816-8 FITTINGS
AN822-8 ELBOW
AEROQUIP 601-8 HOSE
AEROQUIP 601-8 HOSE MUST BE PROTECTED WITH AEROQUIP AE 102-14 FIRESLEEVE USE TWO CLAMPS P/N 900591B PER HOSE.
AEROQUIP 816-8 HOSE FITTINGS
AN823-8 STEEL ELBOW
STEWART WARNER P.N. 8406R OIL COOLER
AN823-8 ELBOW
ENGINE ACCESSORY CASE

TYPICAL OIL COOLER PLUMBING SCHEMATIC.

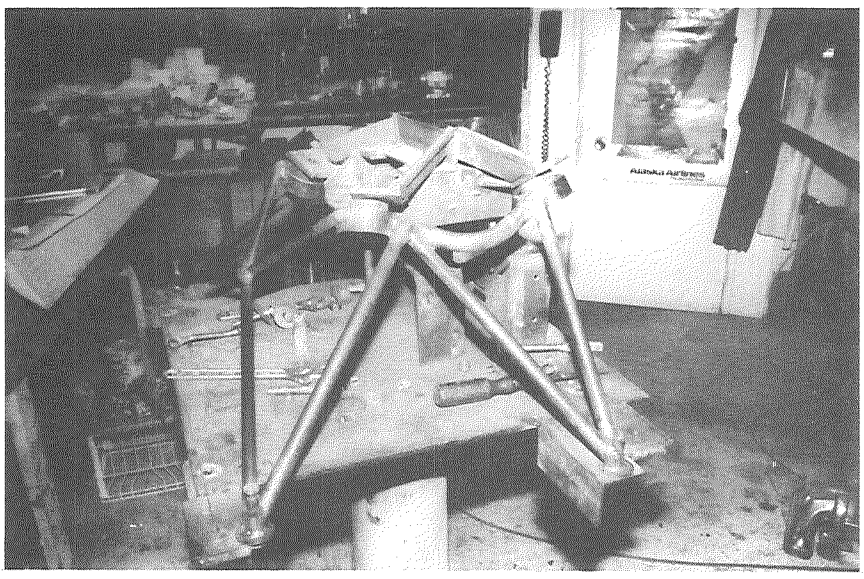
Due to the very small number of Defiants being built, and due to RAF's limited resouces these days, this set of plans does not include a detailed list of parts and materials required to install the two engines and all of their systems. RAF will not be setting up a distributor to provide weldments and other engine installation related parts, with the exception of the front and rear cowlings which are available from Featherlite Products, P.O.Box 781, Boonville, CA 95415, 707-895-2718.



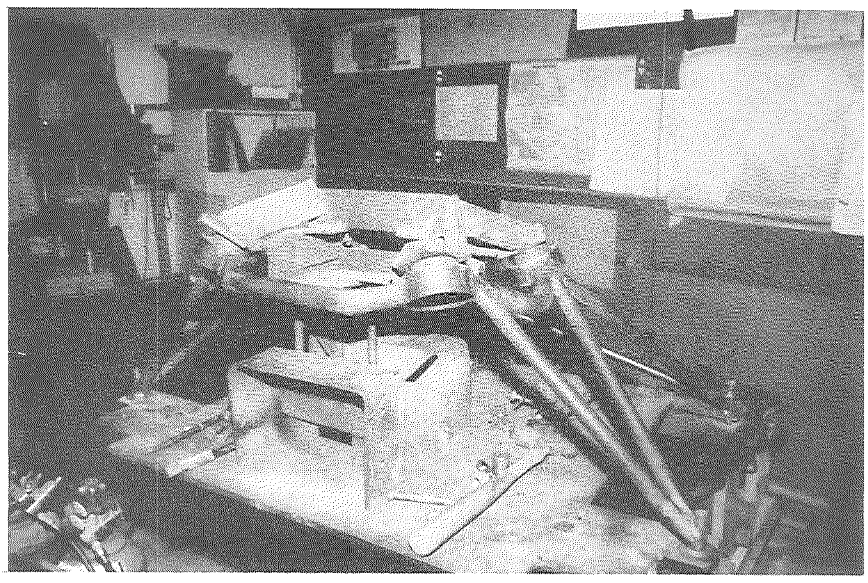
1. Dynafocal engine mount in the welding fixture - viewed from "below" if mount was on the aircraft. Dynafocal "ring" can be purchased prefabricated from RAF distributors.



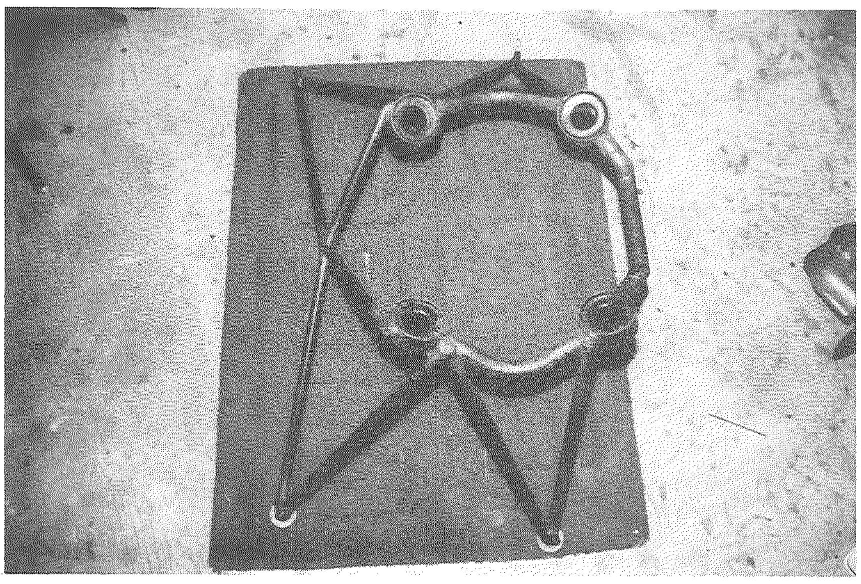
2. View from right side, if on the aircraft, of dynafocal engine mount in the welding fixture.



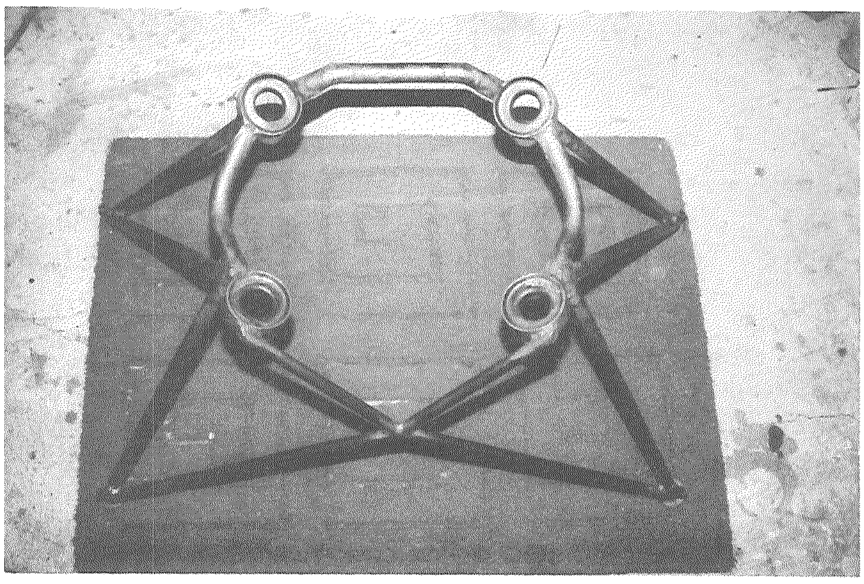
3. View from left side of dynafocal mount in Fred Keller's welding fixture.



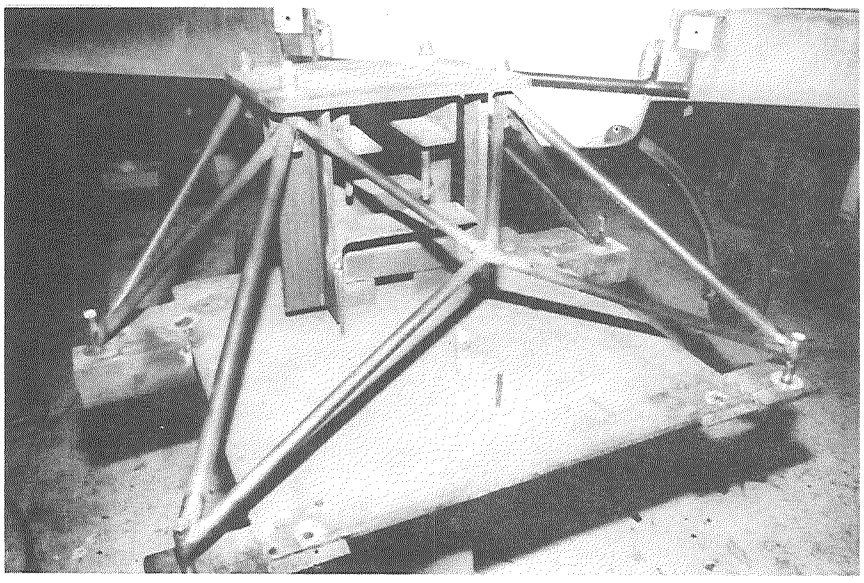
4. View from top/right, dynafocal engine mount. Mount remains bolted into place in the fixture until all welding is complete and the weldment has cooled completely.



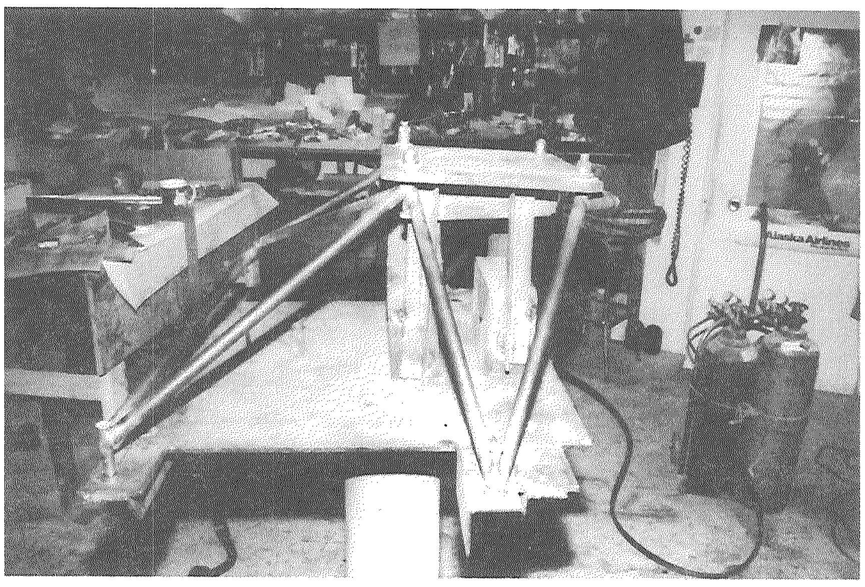
5. Top view of finished dynafocal engine mount.



6. Another top view of engine mount - ready to clean up and paint.



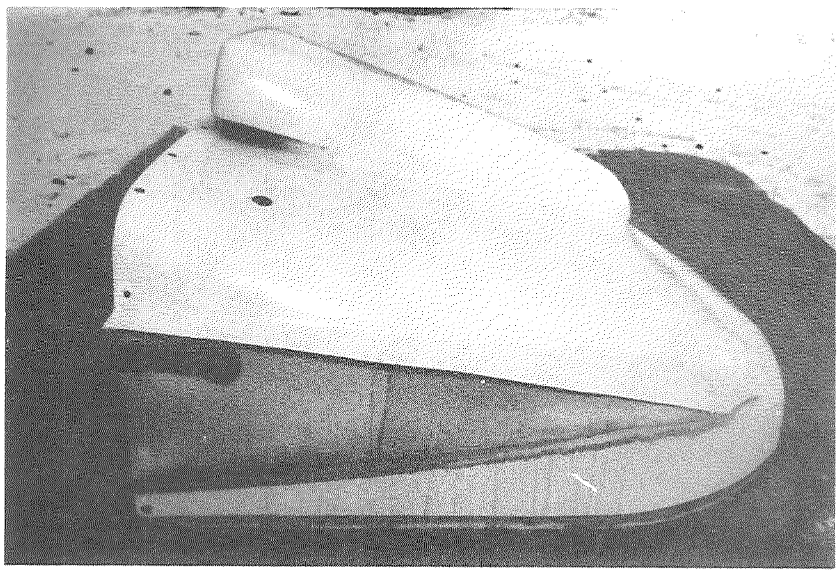
7. View from the bottom right side of a conical engine mount, bolted into a welding fixture during manufacture.



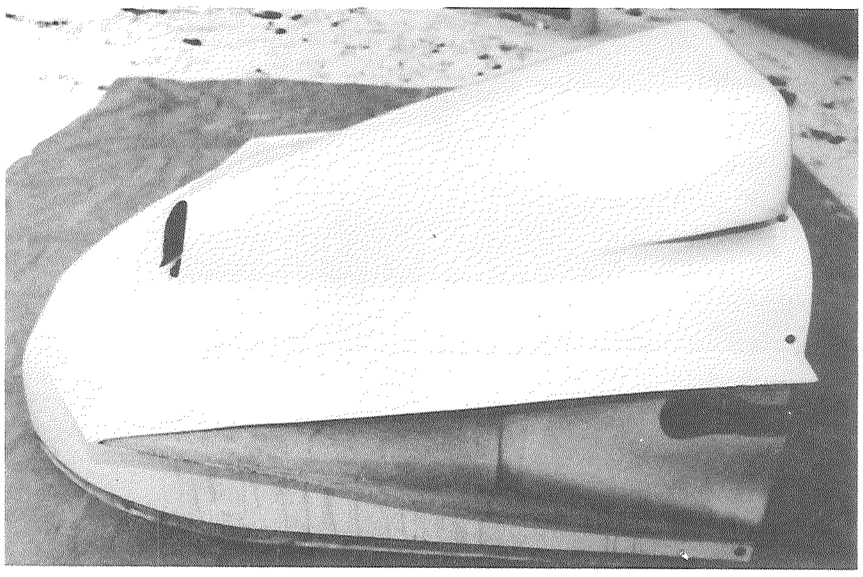
8. View of left side of conical engine mount in the welding fixture.

9. Rear engine cowling. The first pieces of foam are stacked around the plastic wrapped engine.

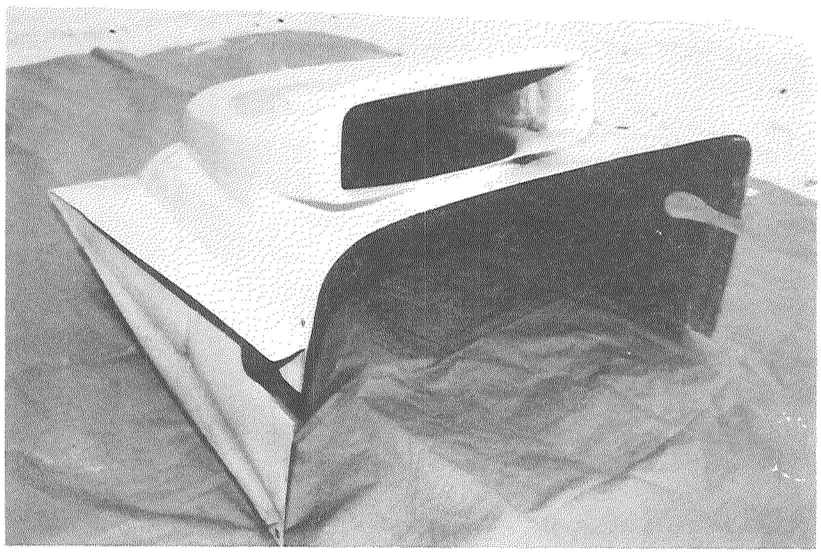
10. Right side view. Fred used plenty of nails to hold foam pieces together. We have found that the pour-in-place foam, such as Liquid X-40 works very well as a 'glue' to stick the foam pieces together. This allows you to remove all nails after the foam cures, which makes it easier to carve.



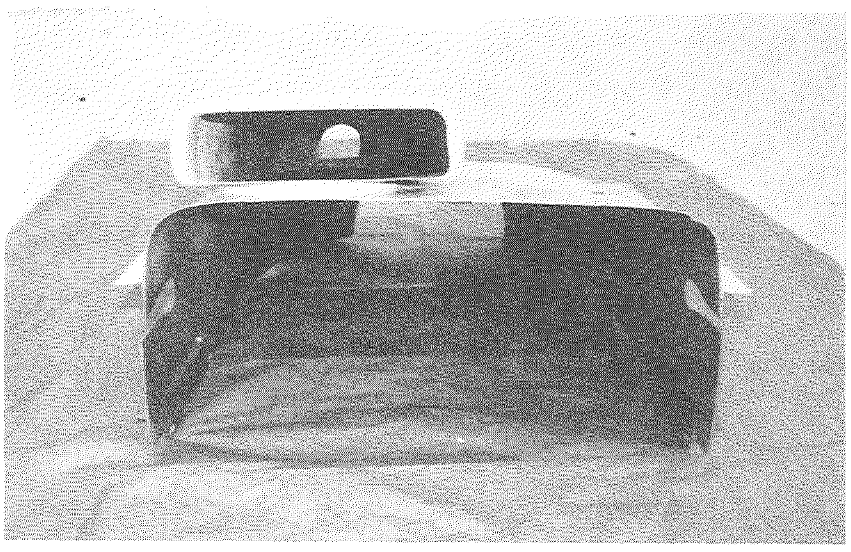
11. Finished rear cowl, lower half, view of right side.



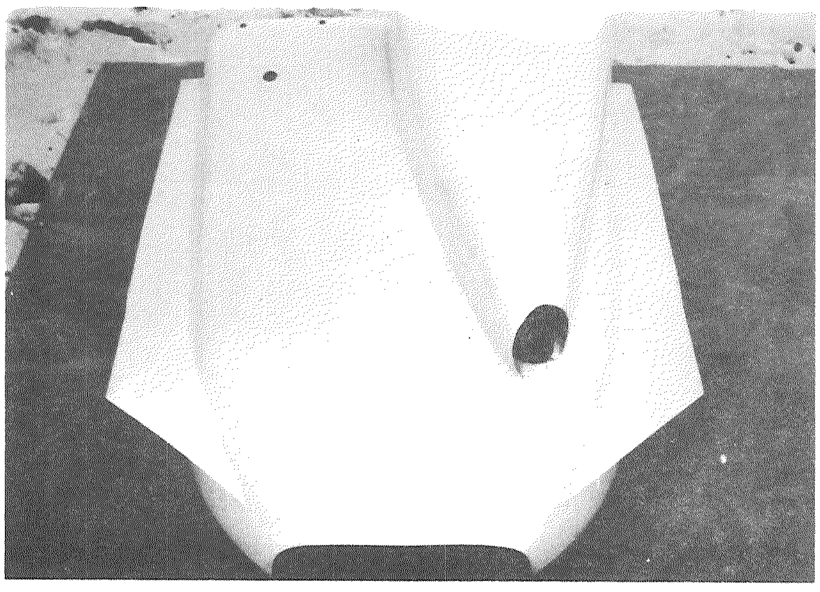
12. View of left side of lower half of rear cowl. Note how intake is offset to left side.



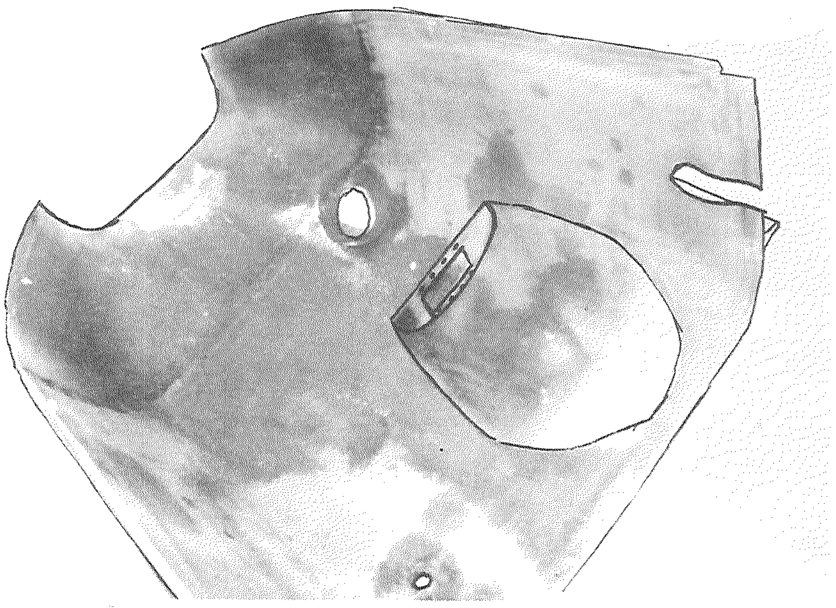
13. Lower half of rear cowl. Note how cooling air intake is below cowling surface. This is to ensure that only high speed ram air enters the intake and that slower moving boundary layer air is split off and around the inlet.



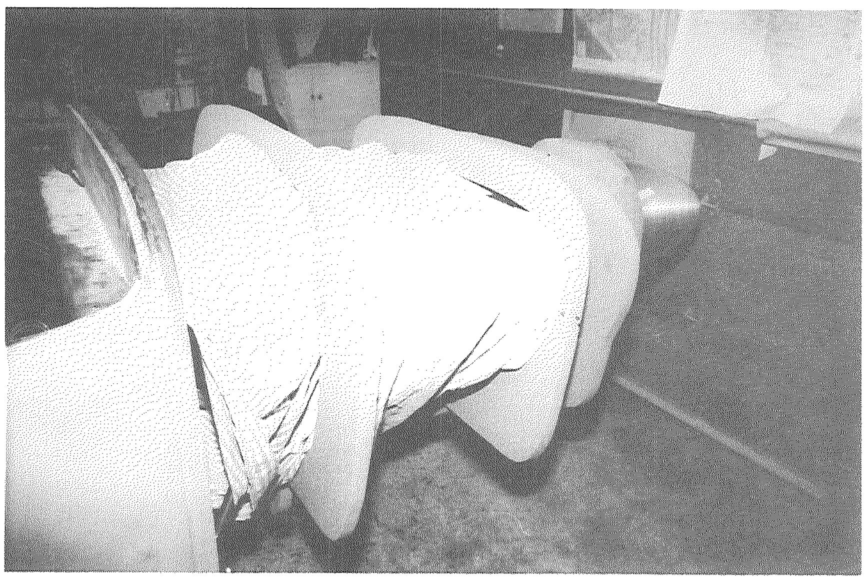
14. Lower half of rear cowl. Note the hole in the aft of the intake blister. The exhaust and the oil cooler cooling air flows out through this hole. The oil cooler mounting flange can be seen, just forward of the exhaust hole.



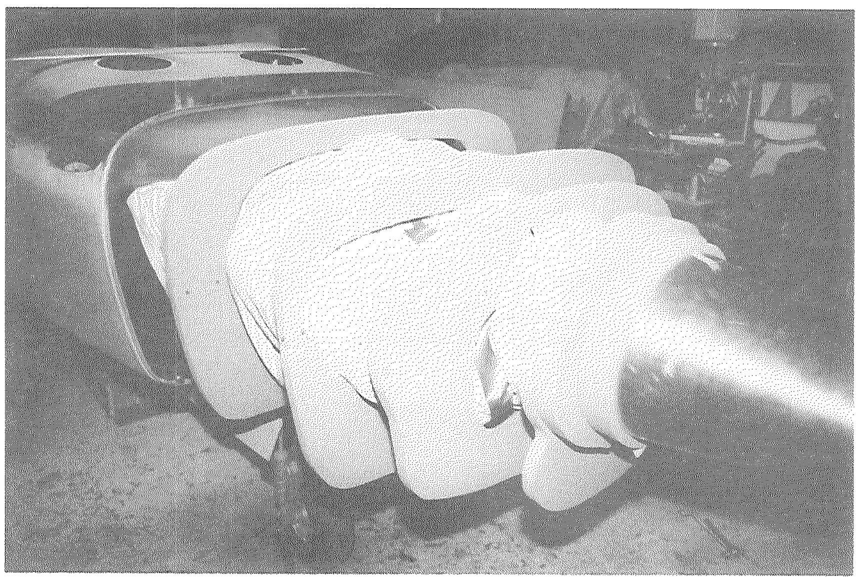
15. Rear view of lower half of rear engine cowling. Note intake offset to left side (when mounted on airplane). Note exhaust pipe, and oil cooler, cooling air vent. Small hole near leading edge of cowl is for engine breather.



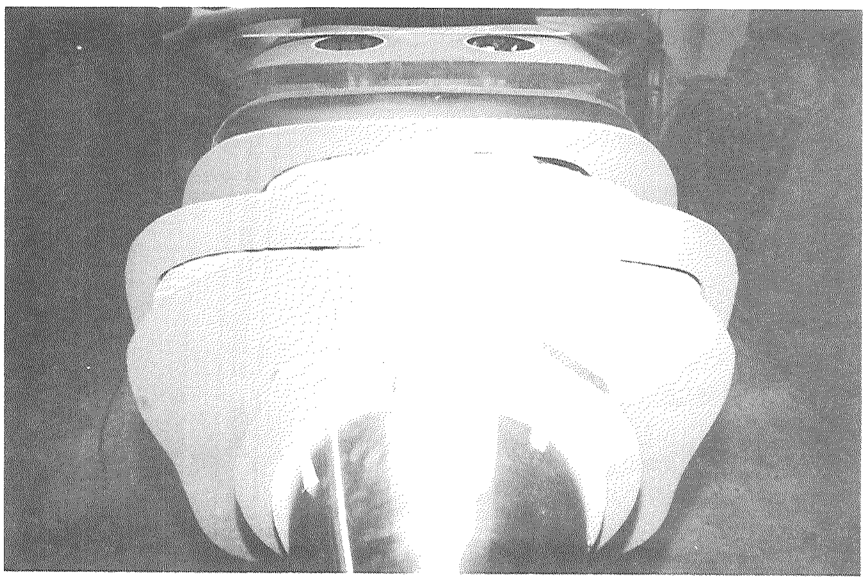
16. View of inside of rear engine lower cowling. Note oil cooler mounting flange. Slot in side of cowl is to clear aileron torque tube (C-27).



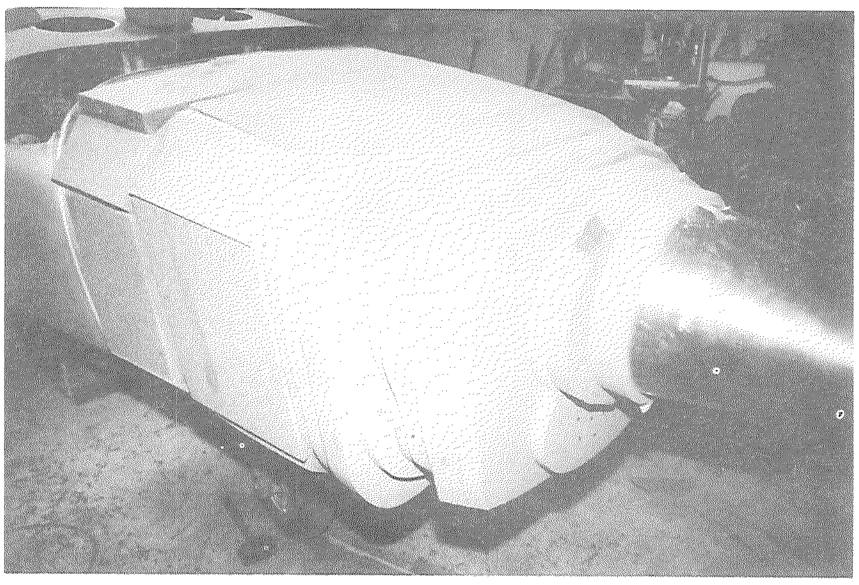
17. Wrap front engine with plastic (garbage bags work great), cut foam shapes called out on page out of 1" thick urethane.



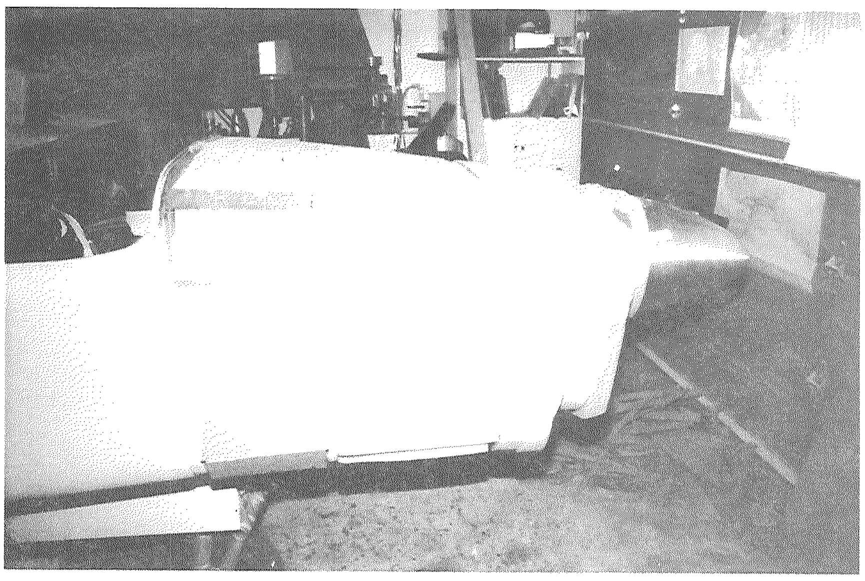
18. Position each 1" thick piece as called out.



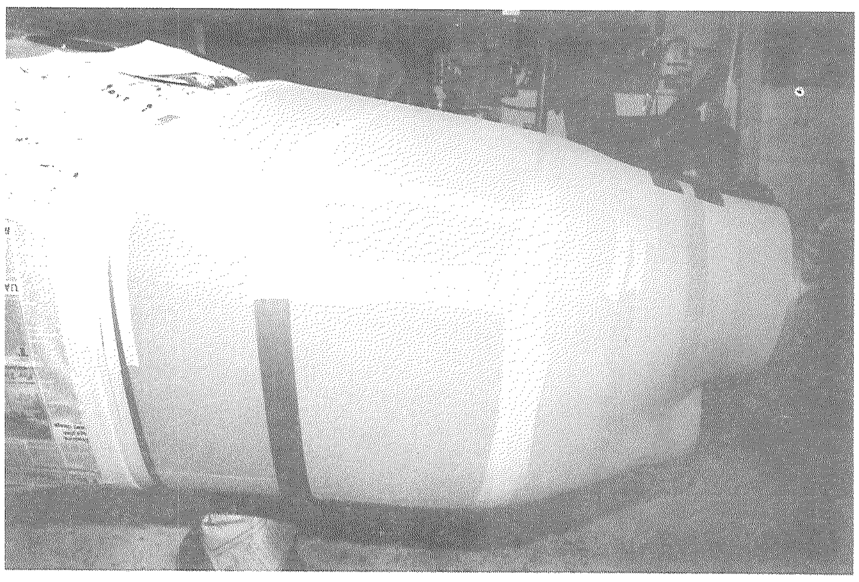
19. Front view showing spinner taped into position on the spinner back plate.



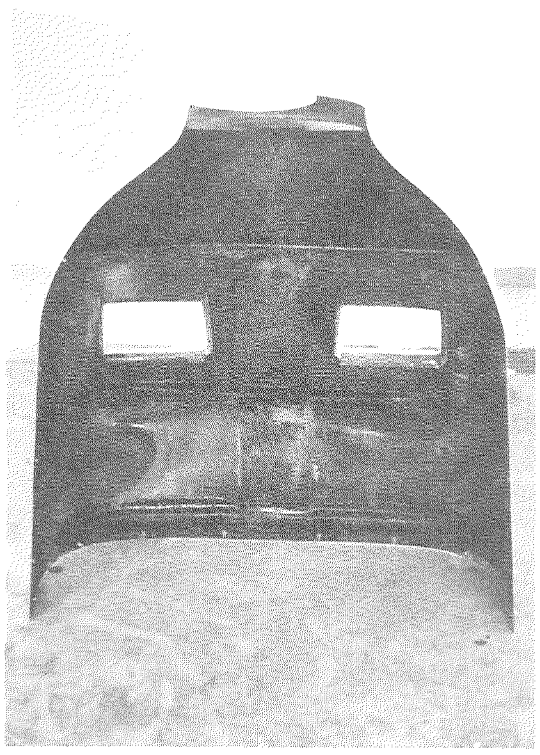
20. Fill in between the foam ribs with scraps of urethane foam.



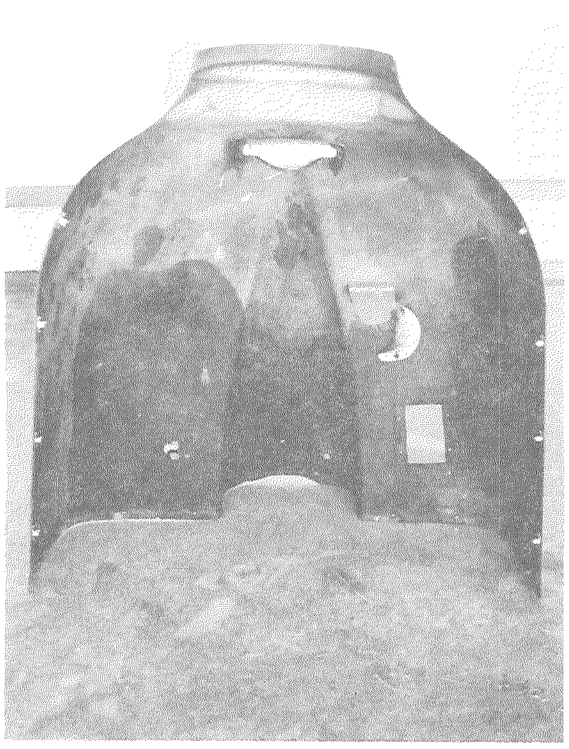
21. Any voids can be filled with pour-in-place foam such as Liquid X-40.



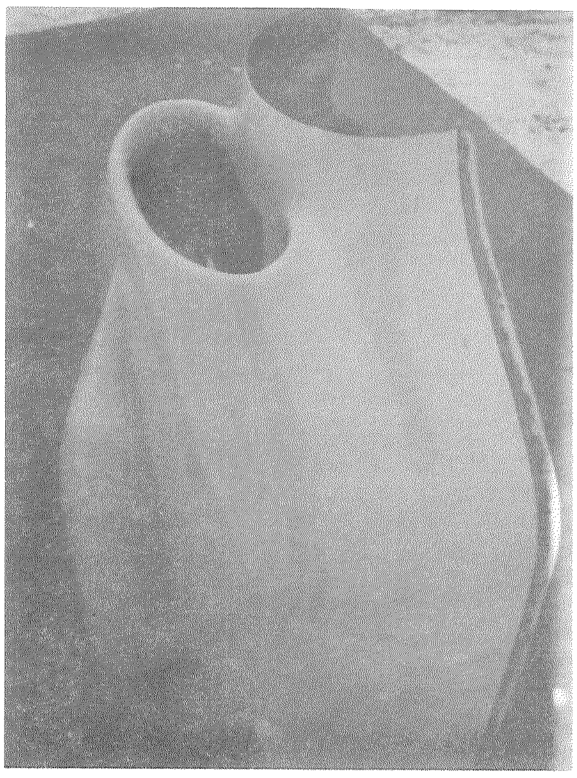
22. Carve away everything that does not look like a cowling!



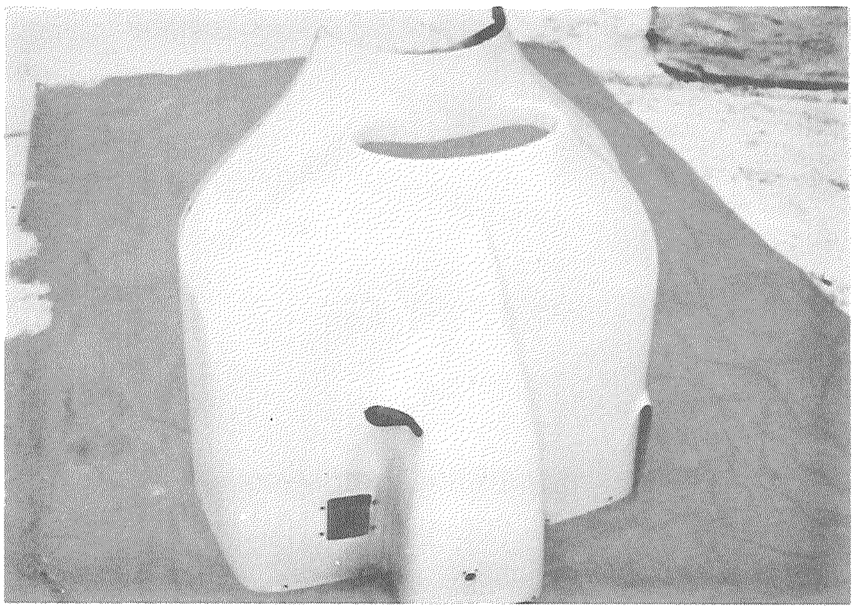
23. Front, top cowling, looking inside. Note cooling outlets and stiffening ribs.



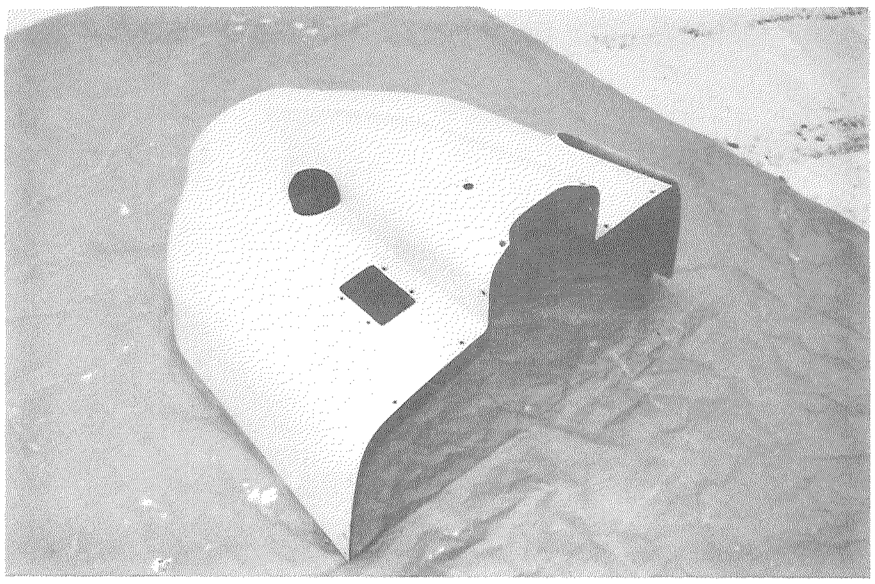
24. Front lower cowl, inside view. Note the position of the landing light and the oil cooler mounting.



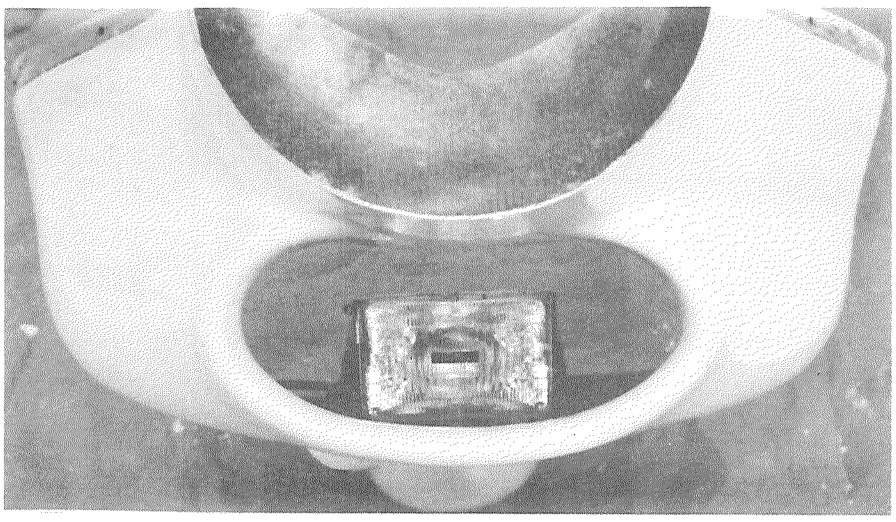
25. Front lower cowl, showing fairing for nose gear and cooling inlet.



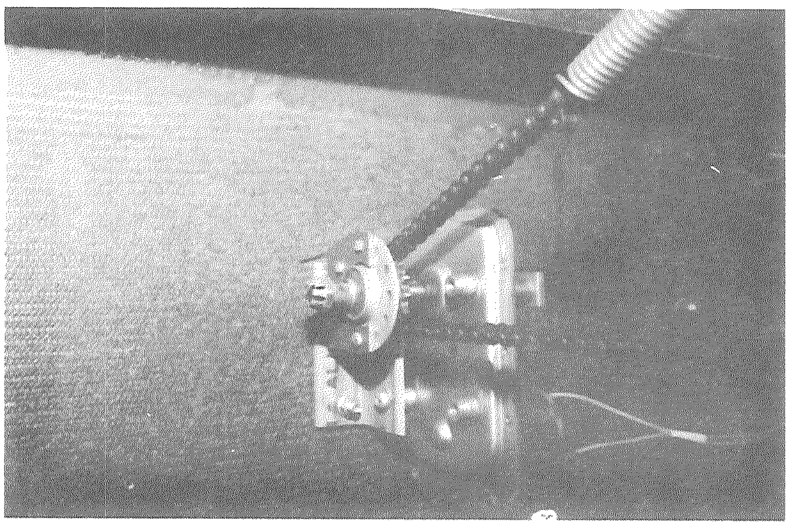
26. Front lower cowl, note root fairing for rudder, lower right.



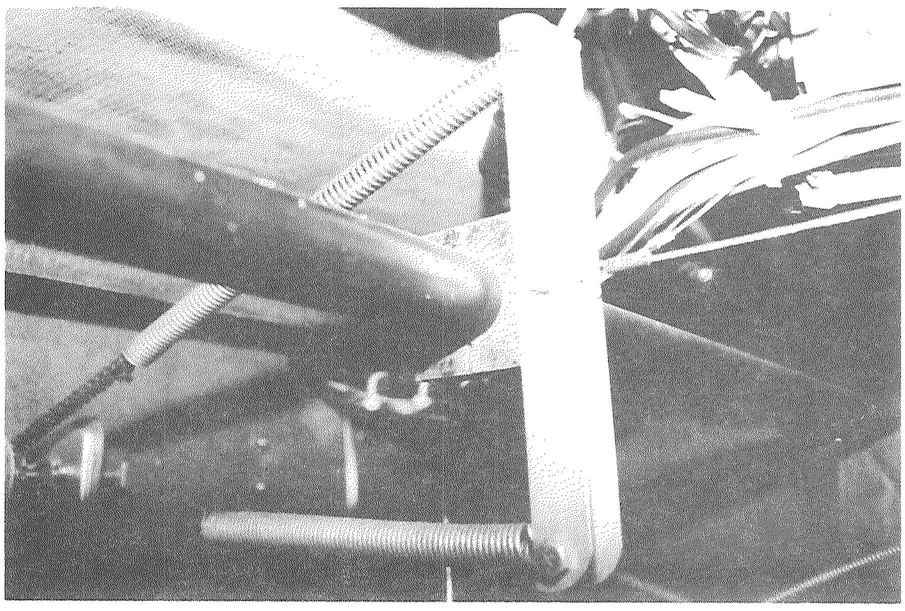
27. Front lower cowl, showing oil cooler mounting place and exhaust pipe clearance hole. Note clearance cut in cowling lip for nose gear steering.



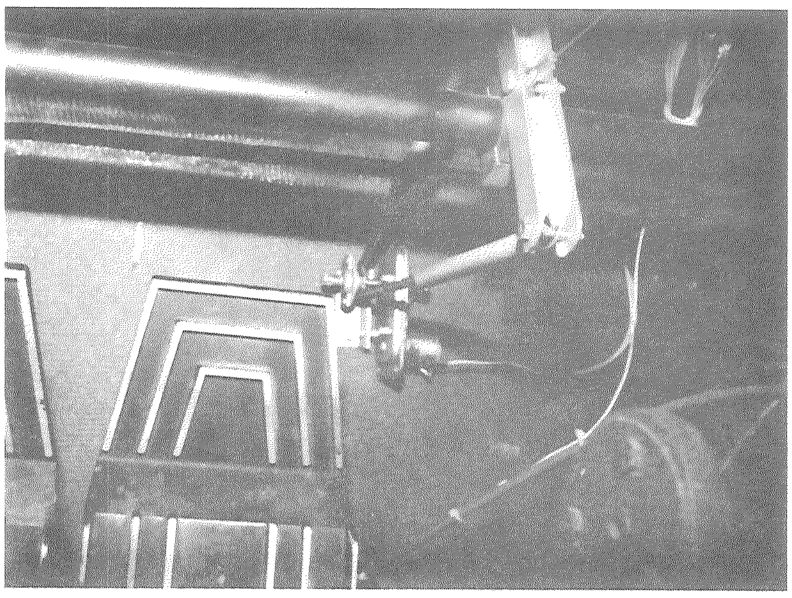
28. Front view of lower front cowl, showing landing light and bulkhead which seals pressure cowl around the prop extension.



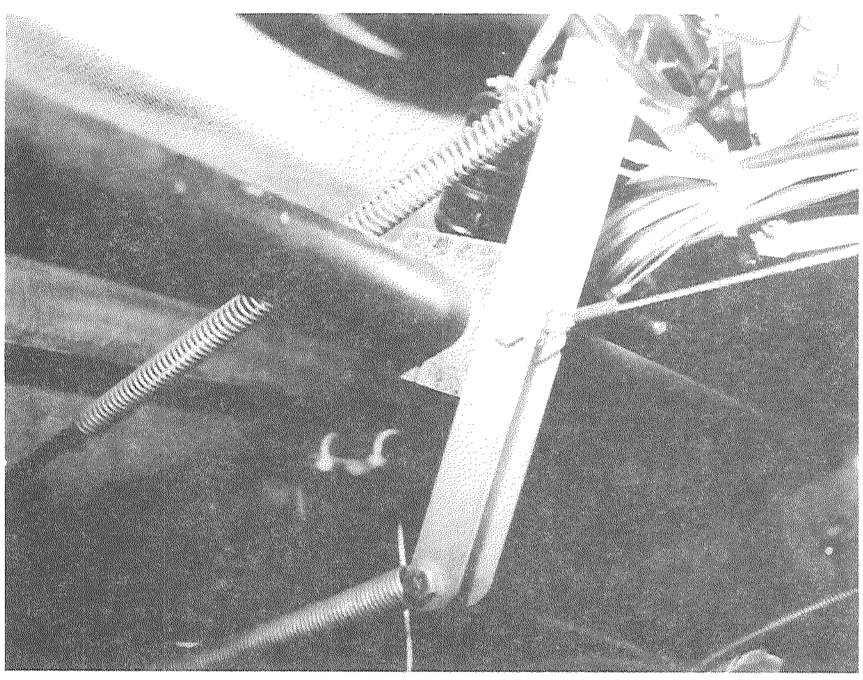
29. Electric pitch trim motor and gear mounted on the aft face of the forward firewall bulkhead.



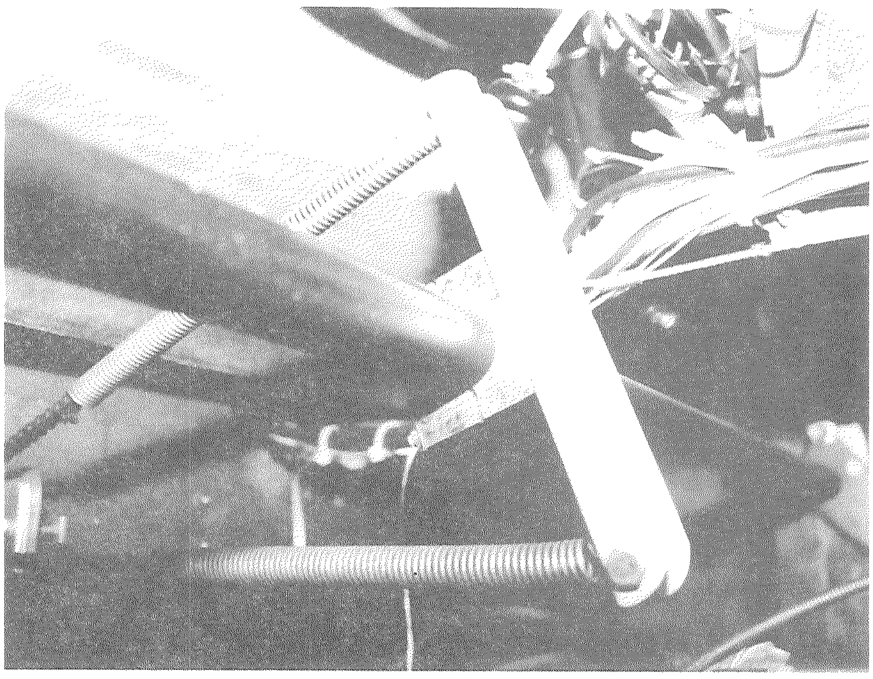
30. Pitch trim belcrank, shown in approximately the neutral trim position.



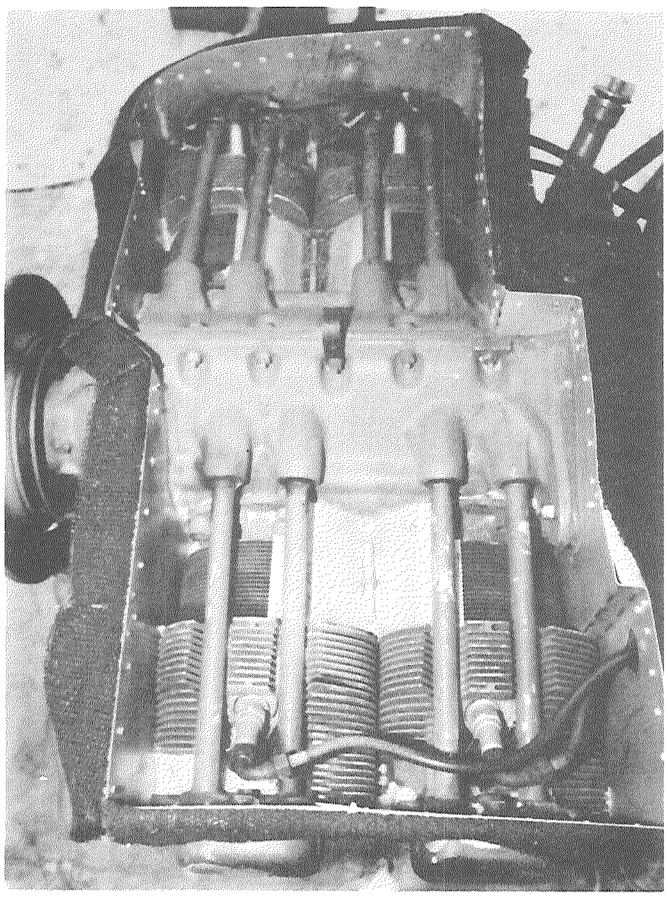
31. View of electric pitch trim mechanism looking forward between the nose gear retract pivot and the rudder pedals.



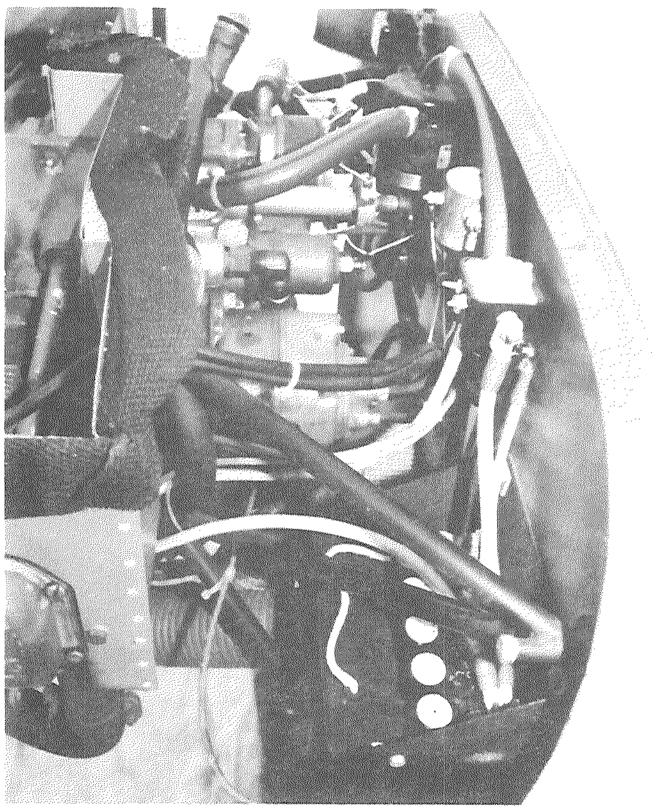
32. Full aft stick with approximately neutral trim.



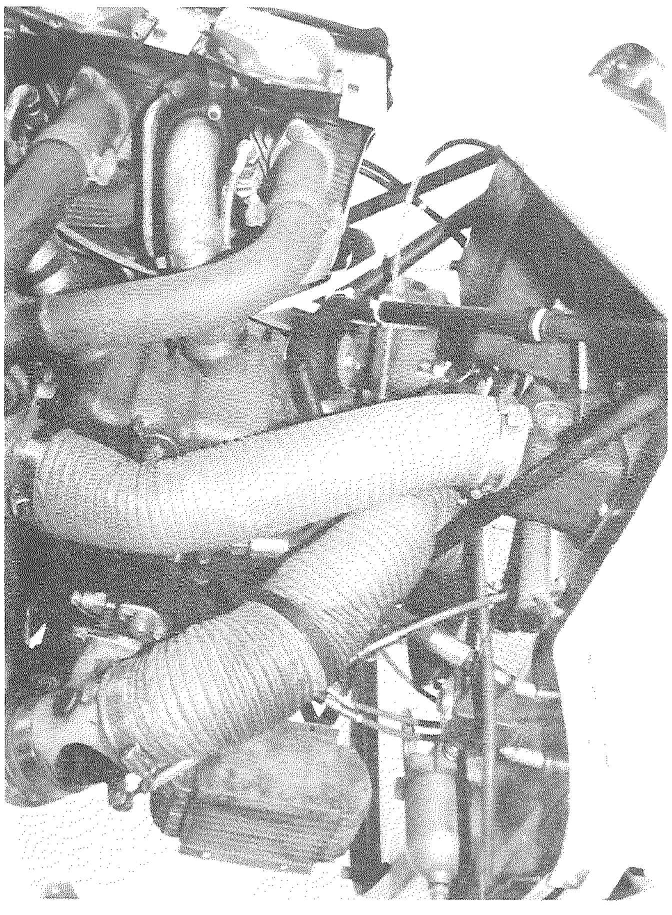
33. Full forward stick with neutral trim. Note construction of pitch trim belcrank, a split block that pinches down onto the elevator torque tube.



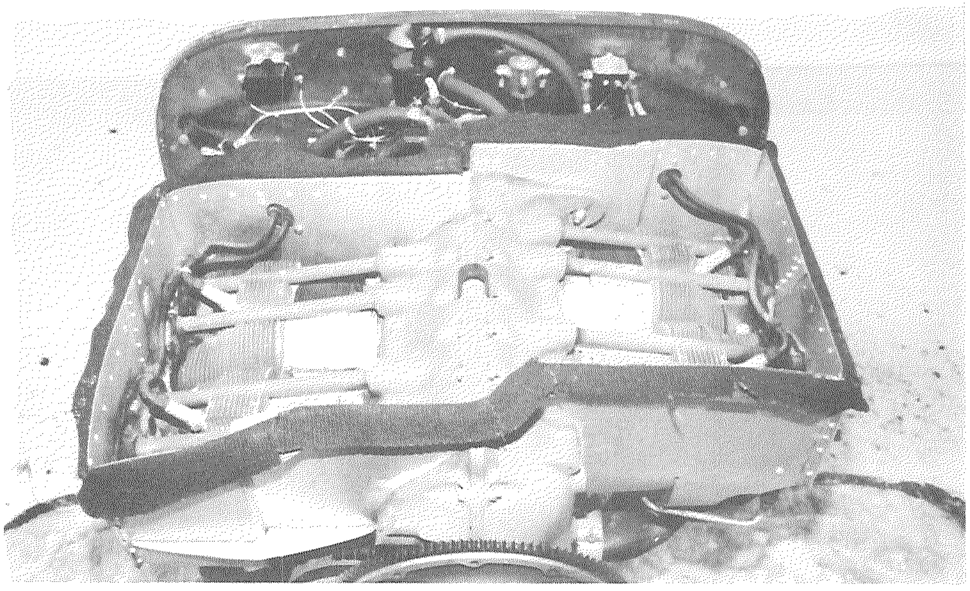
34. Top view of the front engine showing the "basic box" formed by the cooling baffling.



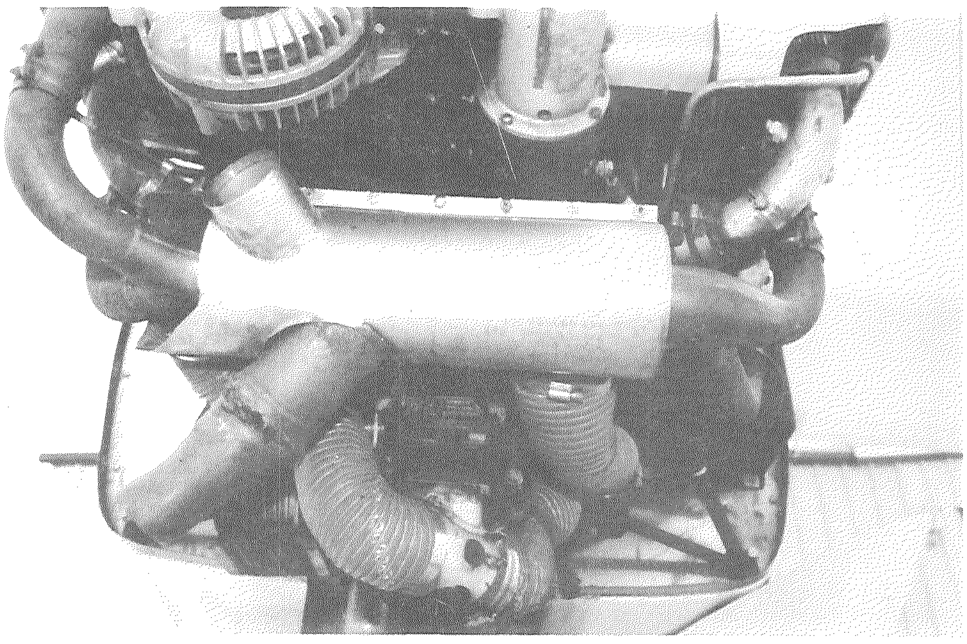
36. View from left side of front fire wall, showing the battery, starter solenoid, master solenoid and oil separator.



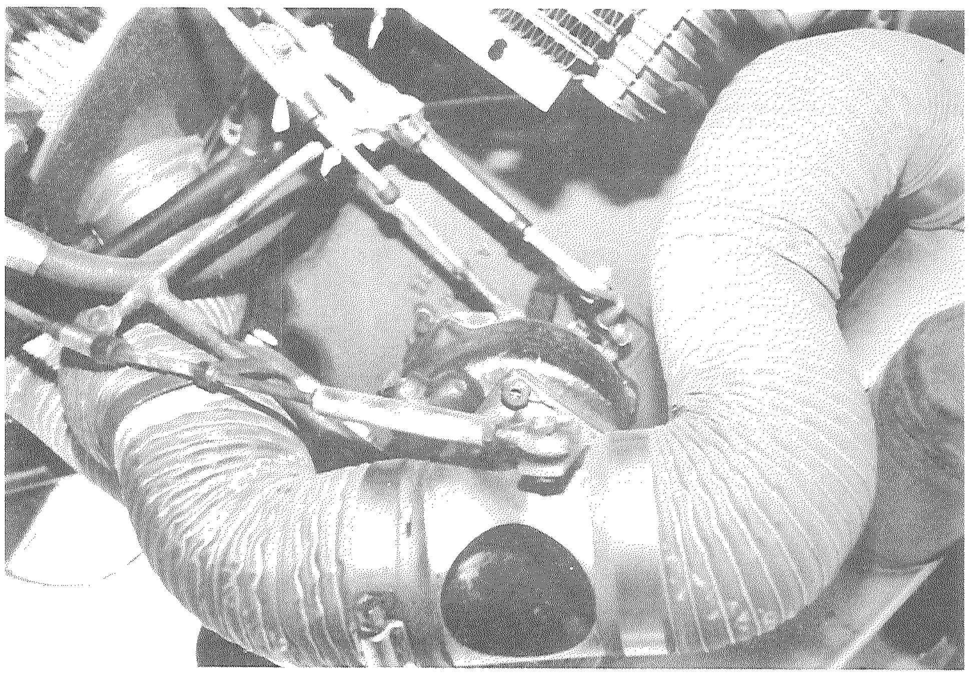
38. View of front engine from left lower side. Note cabin heat duct from heat muff to home made firewall valve.



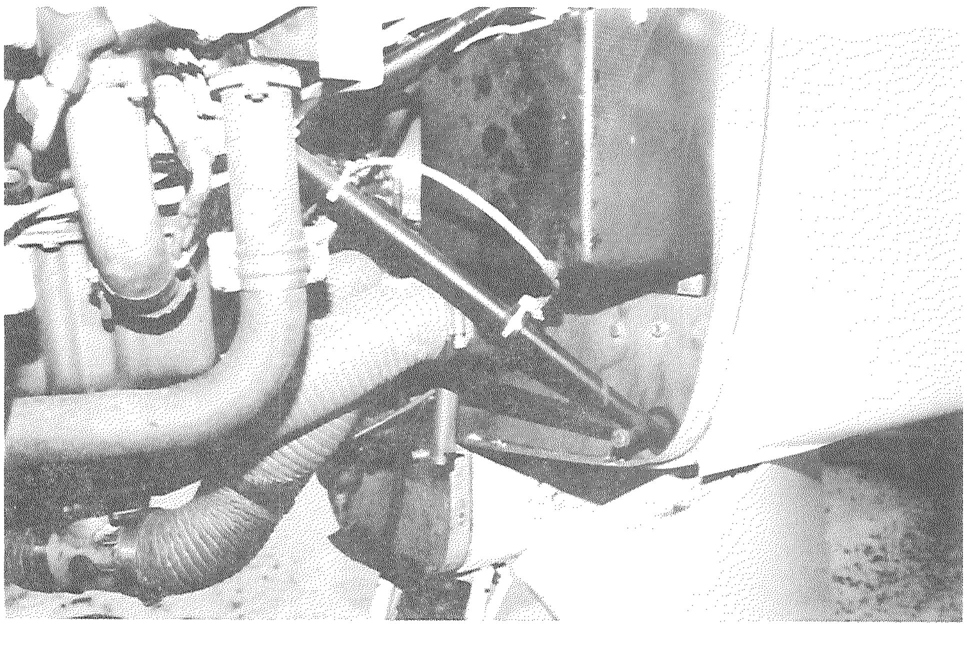
35. Note that the top spark plug wires are routed through the aft bafle using plastic seals part #



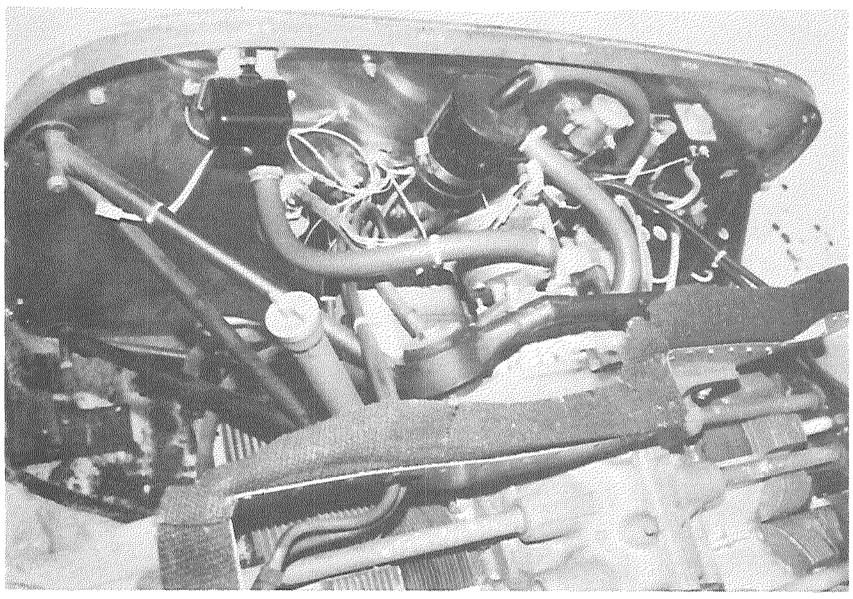
37. Front engine seen from the front. Shows alternator, starter, carb and cabin heat muff and carb heat valve mounted on carburetor.



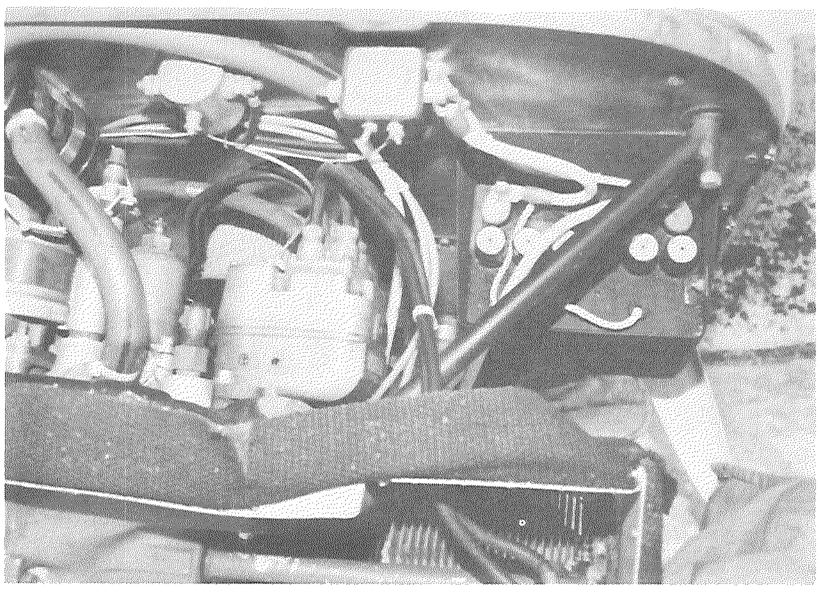
39. Carb heat valve on carburetor. Valve is in normal position, engine breathes throuh the air filter shown in the top left corner.



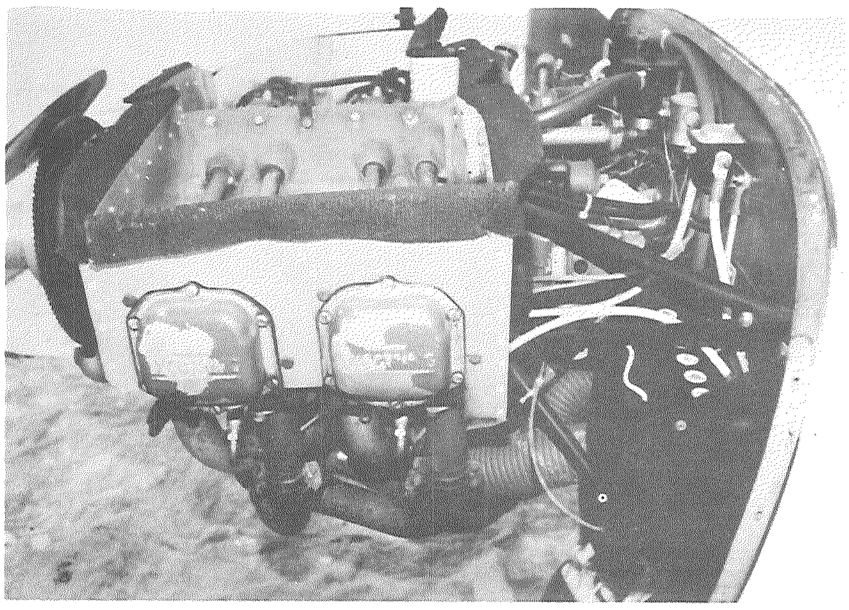
40. Battery box, nose gear box and rudder.



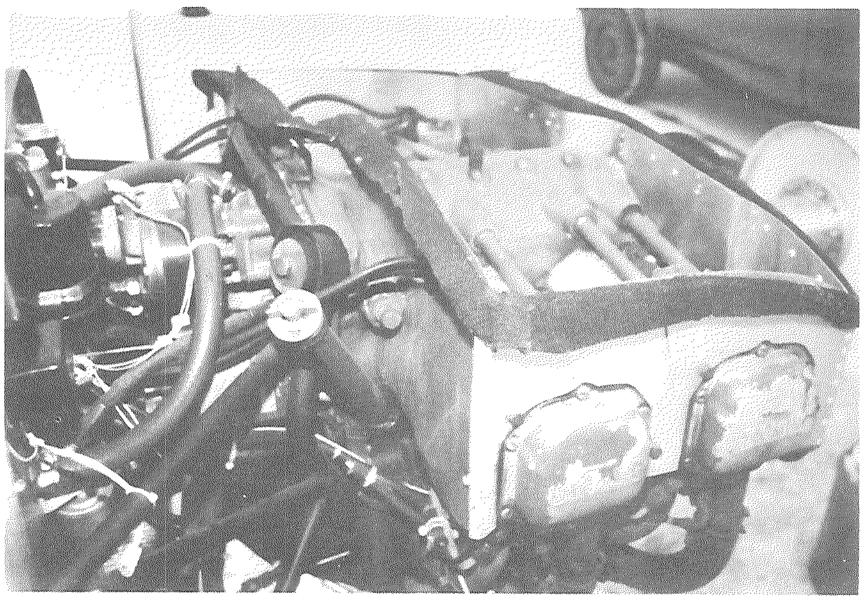
41. Top view, shows dynafocal mount, oil dip stick and on the firewall left to right: voltage regulator, vacumm pump hose to D.G., horizon, oil separator and.......



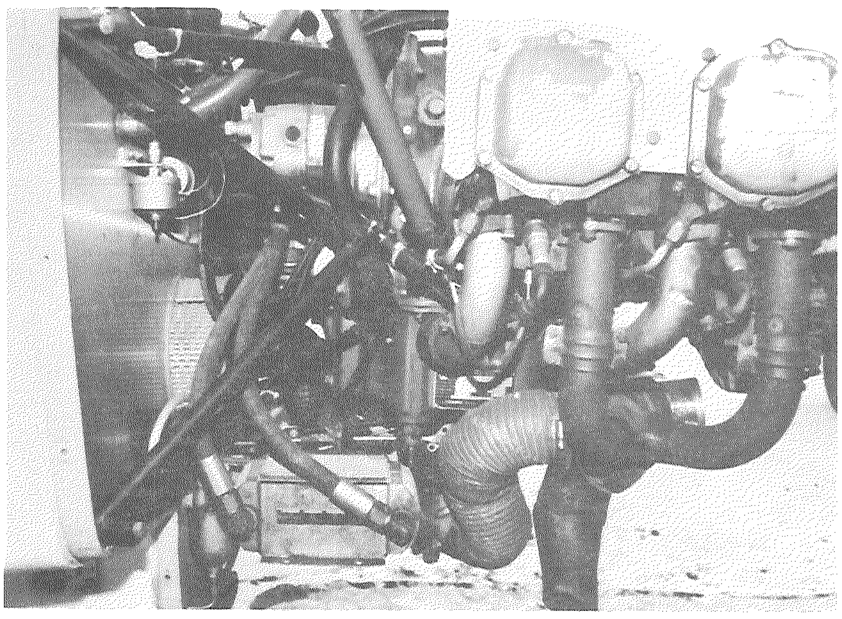
42...Master solenoid switch, starter solenoid switch and battery.



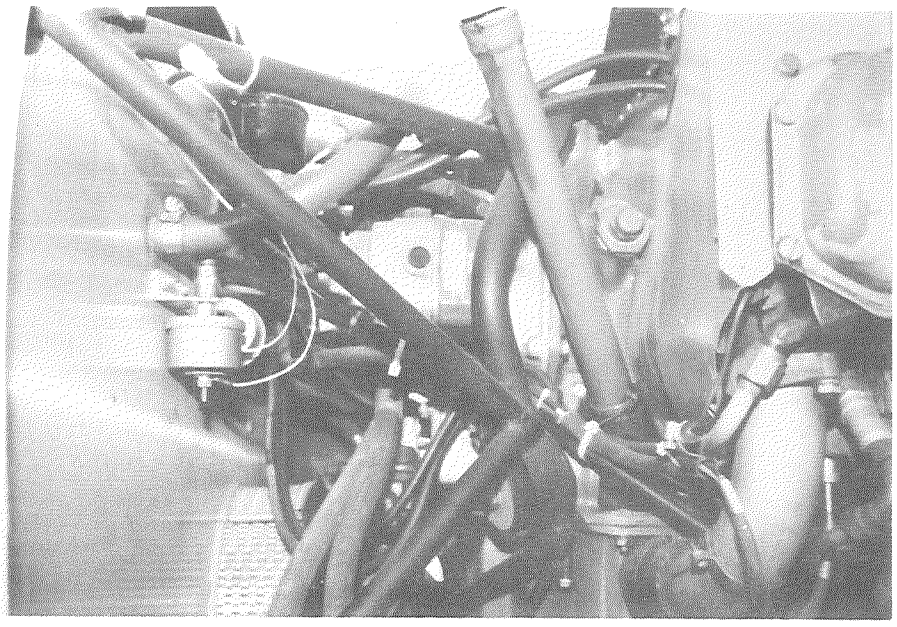
43. Left side view of front engine.



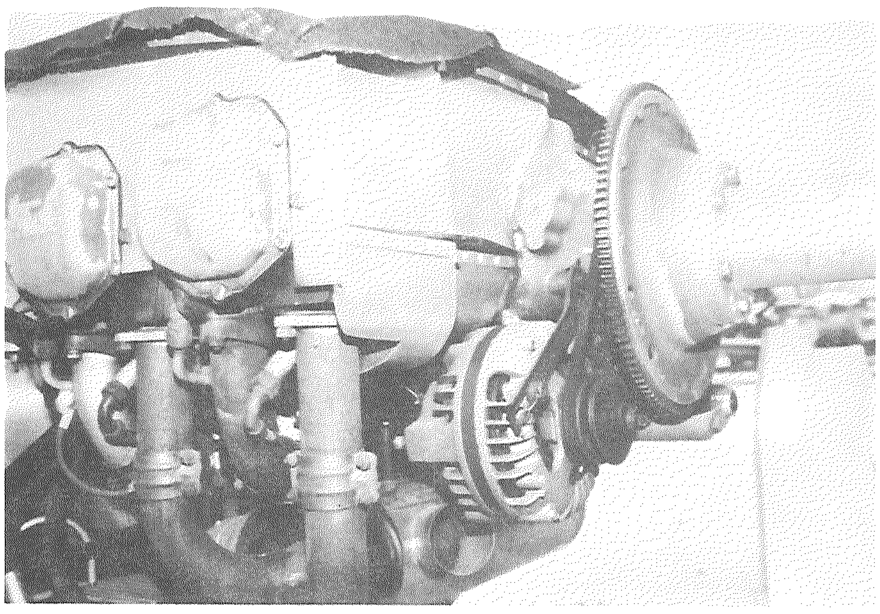
44. Right side view of front engine.



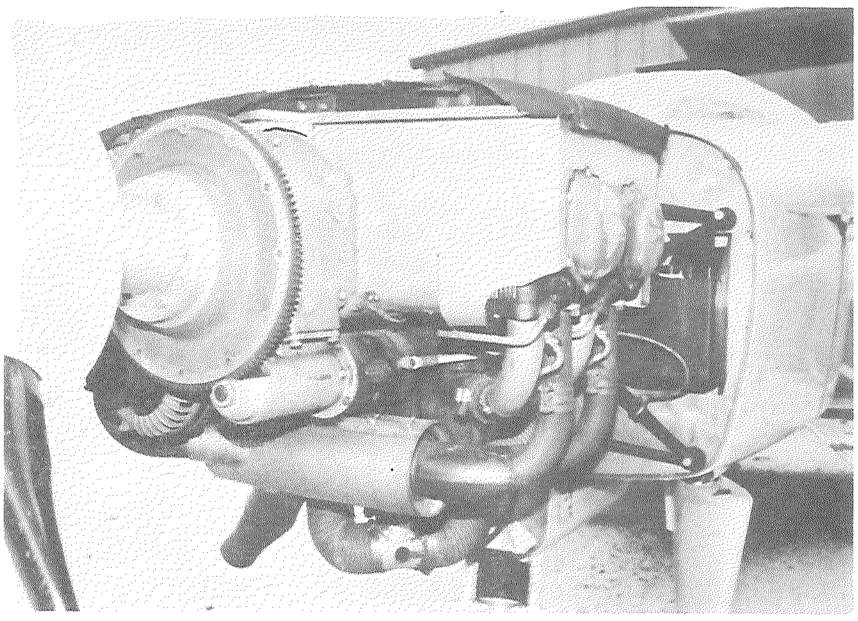
45. Right side view shows oil cooler, carb air intake filter and oil pressure sender.



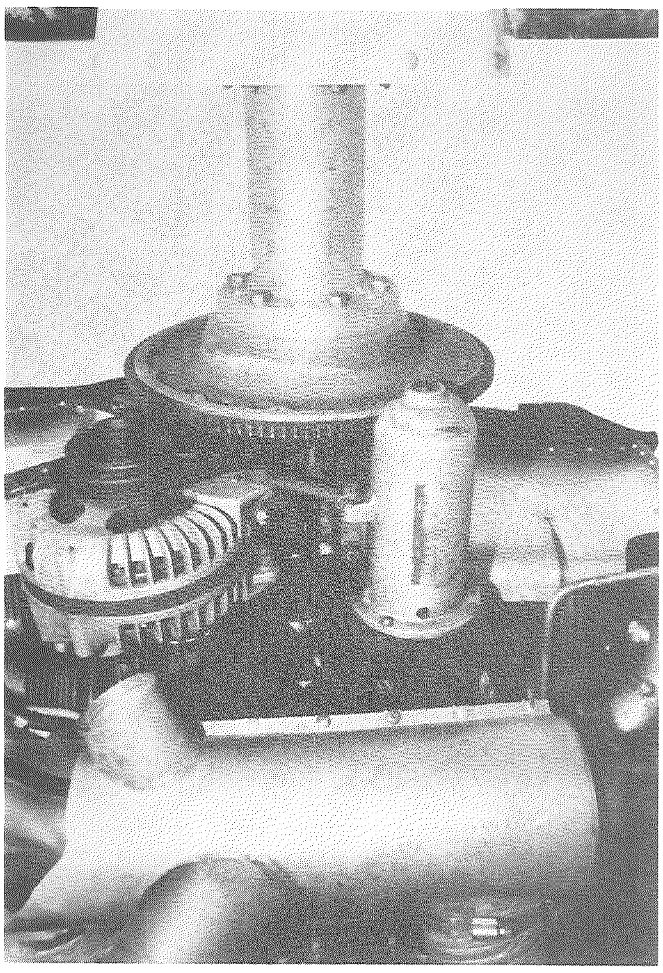
46. Closeup view of remote oil pressure sender, mounted on the firewall. Note dynafocal engine mount.



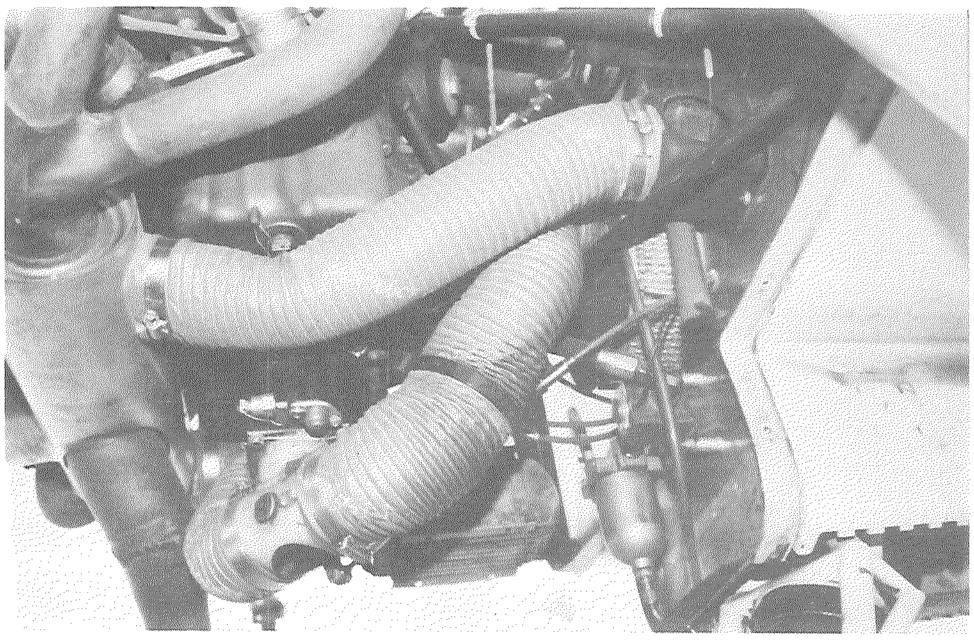
47. View from right forward. Note how front baffle is wrapped under forward left cylinder, also note stiffening rib rivetted to baffle.



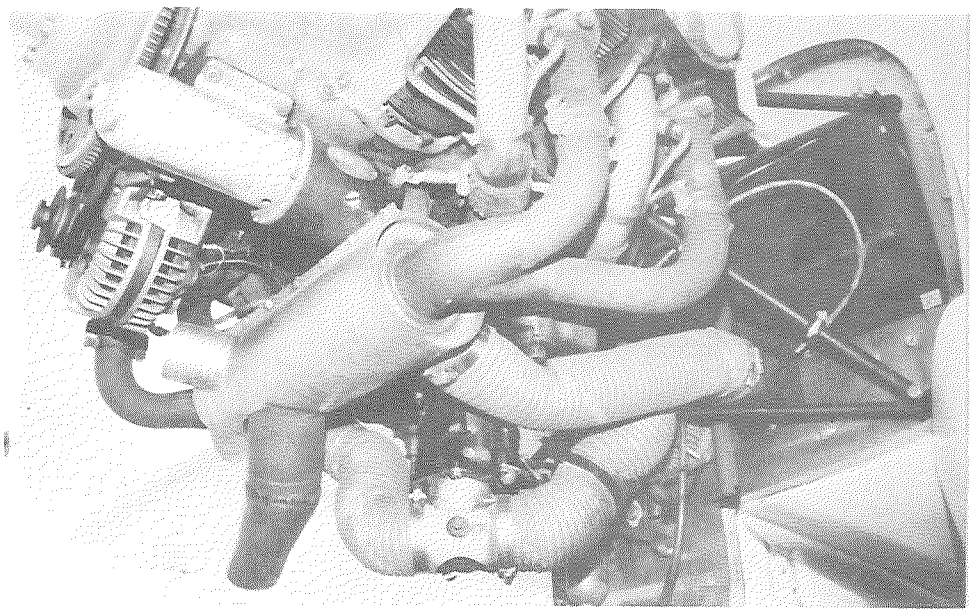
48. View from left forward, again baffling wraps under forward left cylinder.



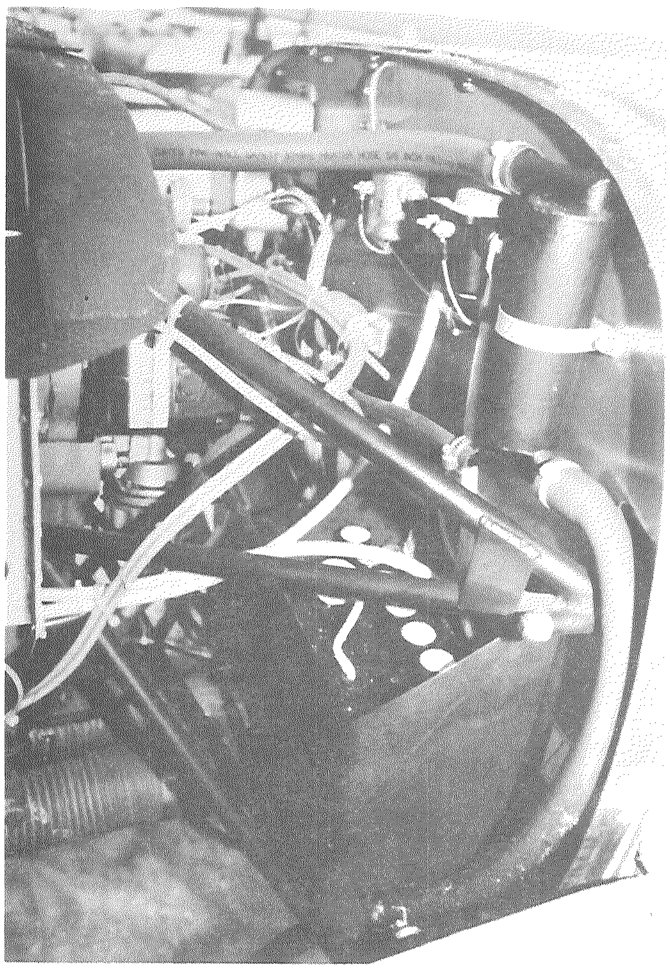
49. View from underneath front engine. Note 8" prop extension used with fixed pitch wooden prop.



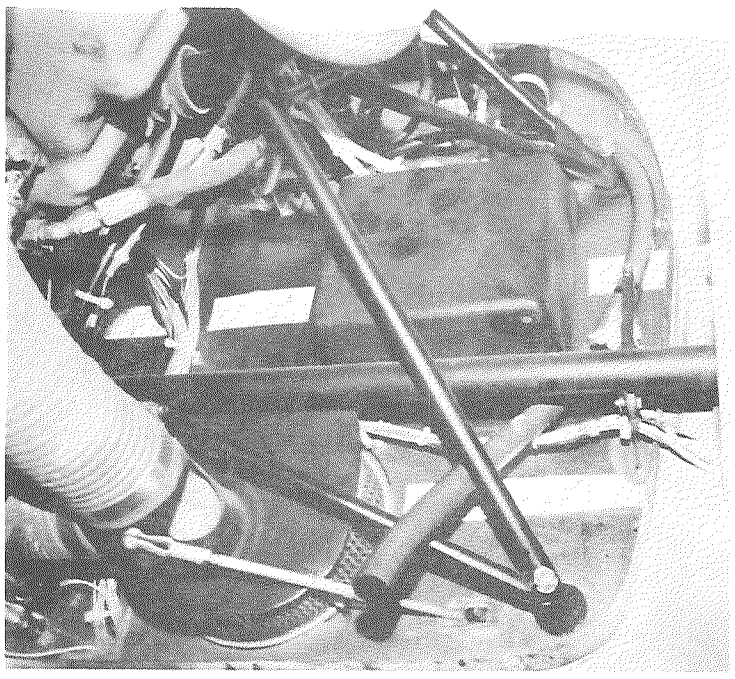
50. Shows position of gascolator and engine breather hose.



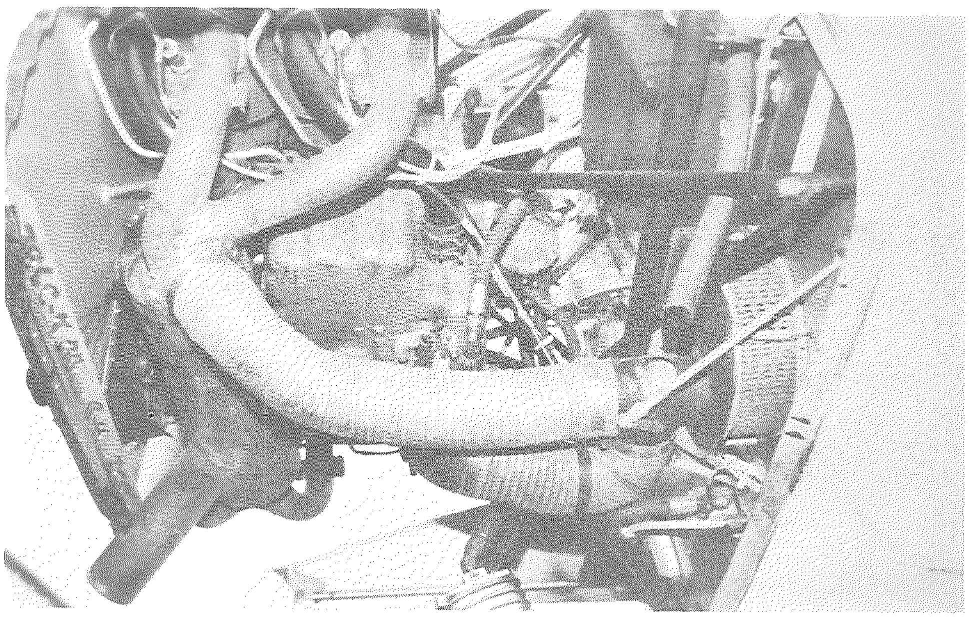
51. Underside of front engine shows exhaust system and heat muff.



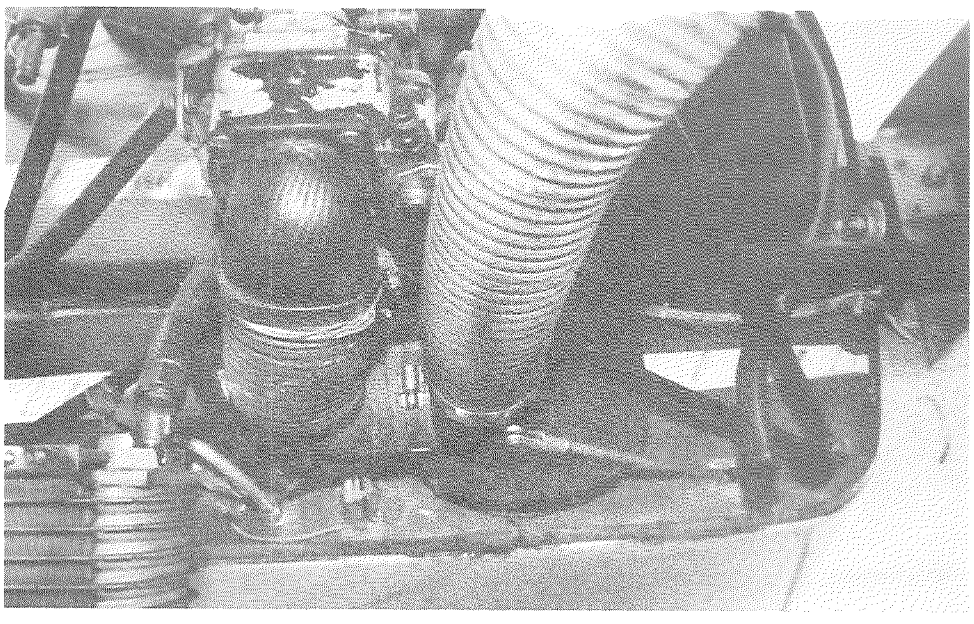
52. REAR ENGINE Shows battery on lower right side of firewall, engine oil separator with breather hose.



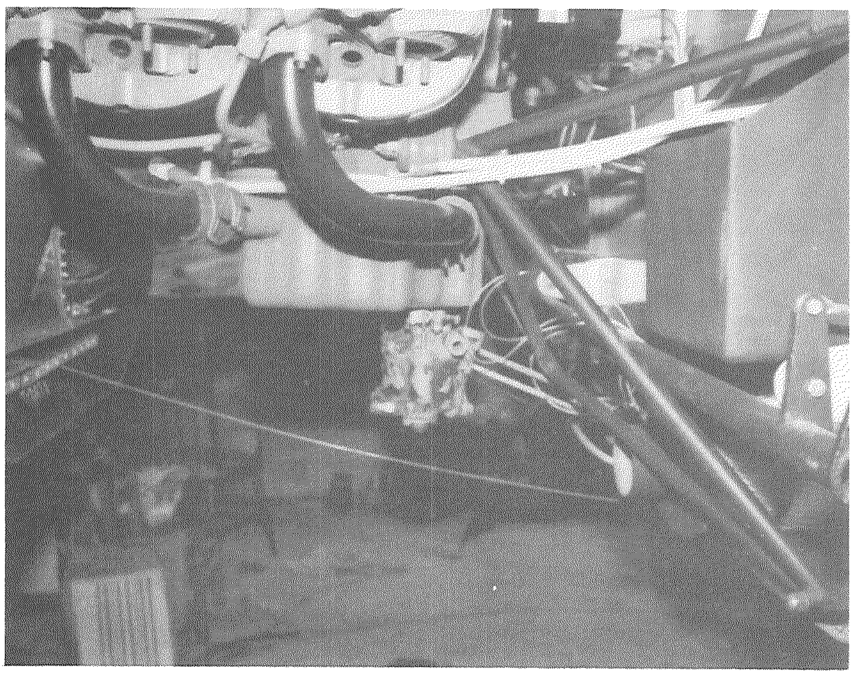
53. Engine air intake filter, breather hose and battery box.



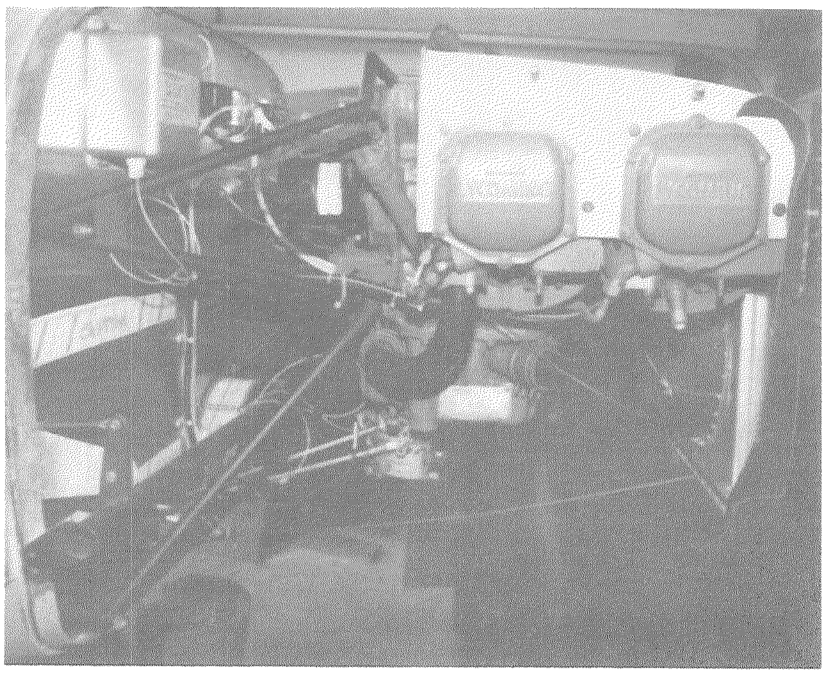
54. Underside of rear engine shows exhaust system, rear baffle with stiffening rib, intake air filter and gasolator.



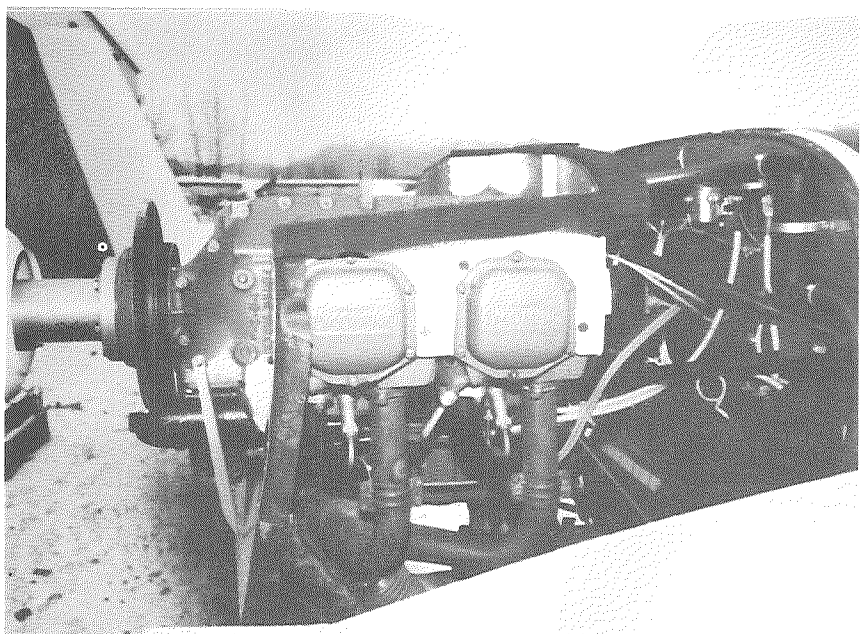
55. Forward view of rear engine shows oil cooler and carburetor air inlet hose and fiberglass elbow.



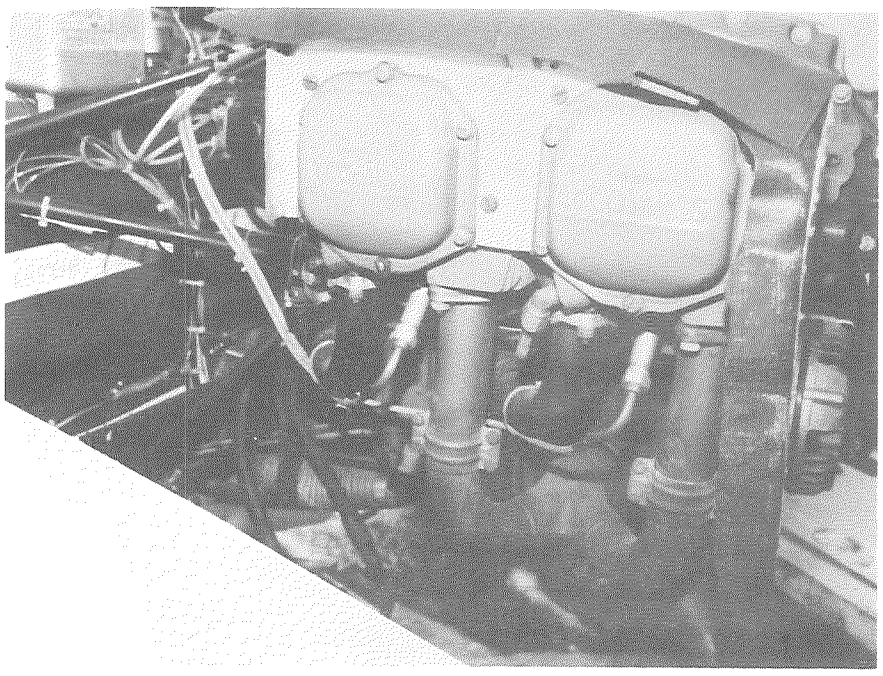
56. Early construction photo of right side of rear engine. Conical engine mount is used.



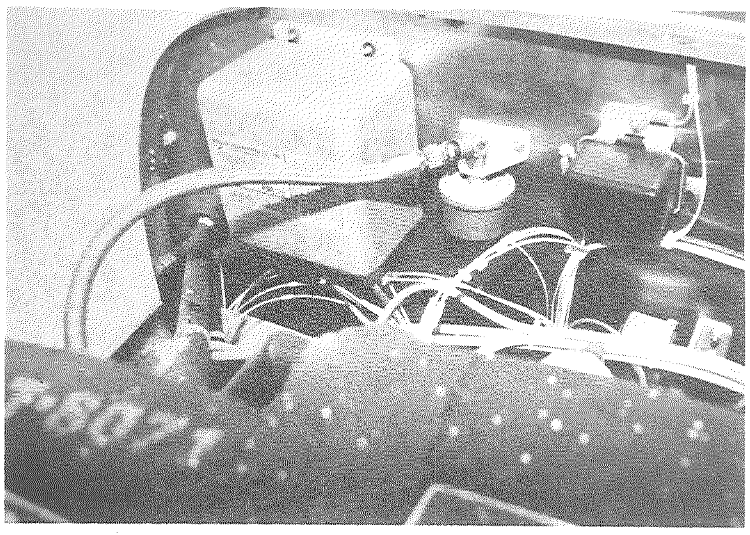
57. Left side of rear engine.



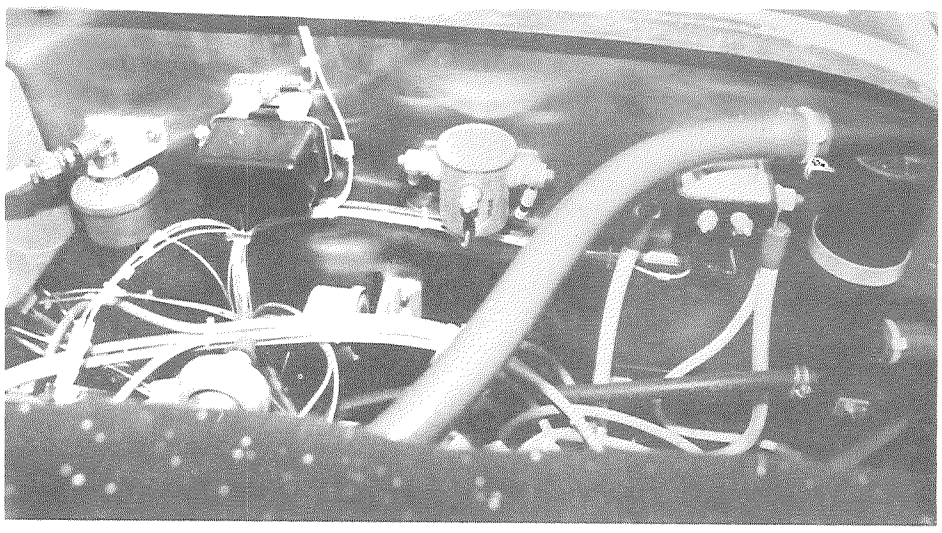
58. Right side of rear engine - note how baffling differs from front engine.



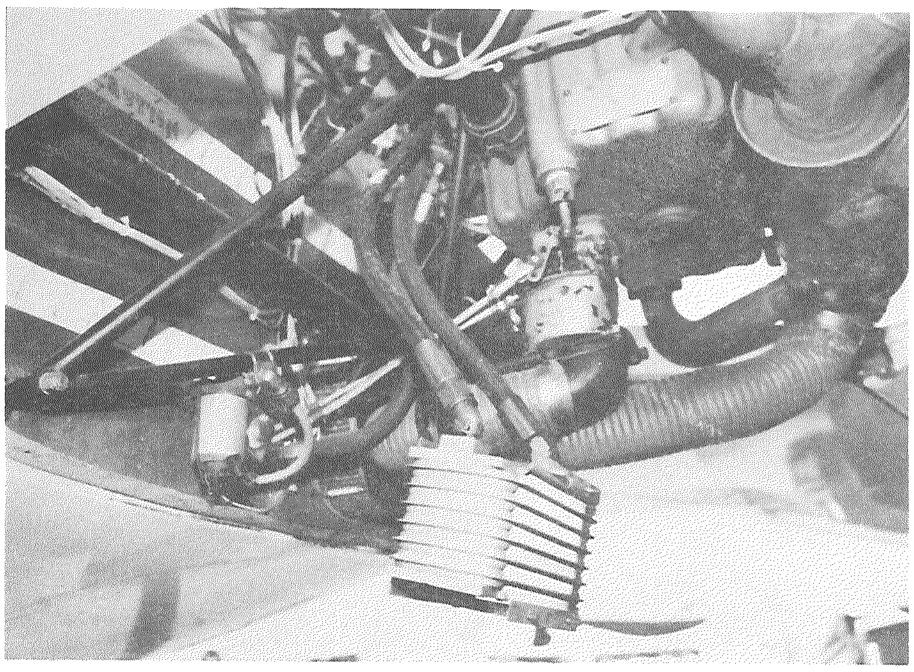
59. Left side of rear engine, shows baffling and wiring details.



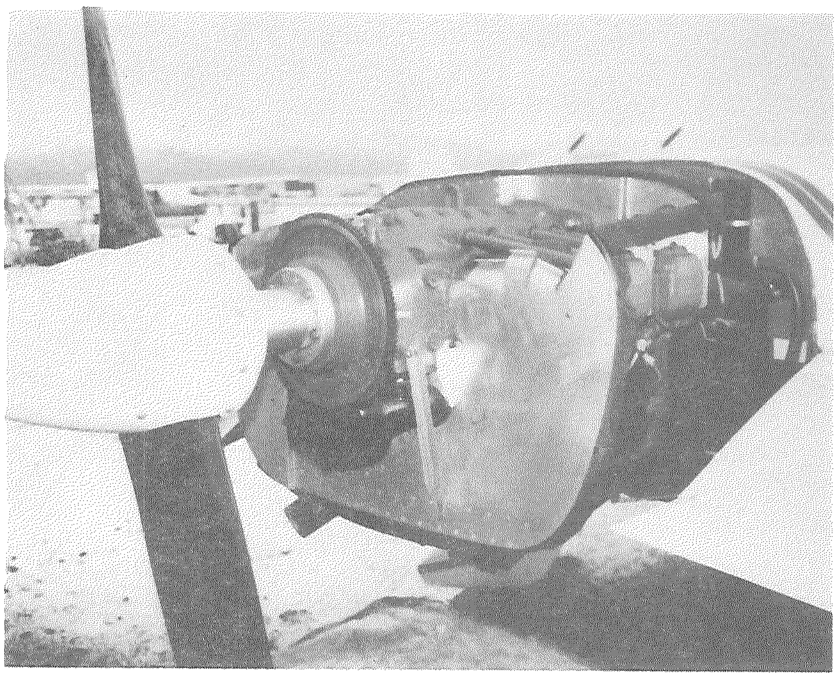
60. Top left side of rear firewall. Left to right: strobe light generator, remote oil pressure transducer and voltage regulator.



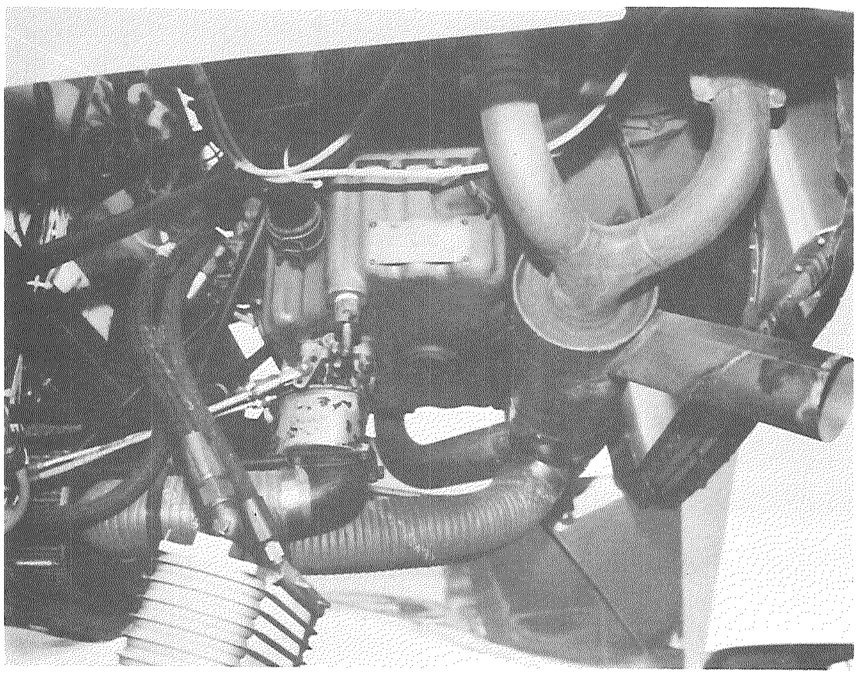
1. Left to right: remote oil pressure transducer, voltage regulator, master solenoid, starter solenoid and oil separator with breather hose.



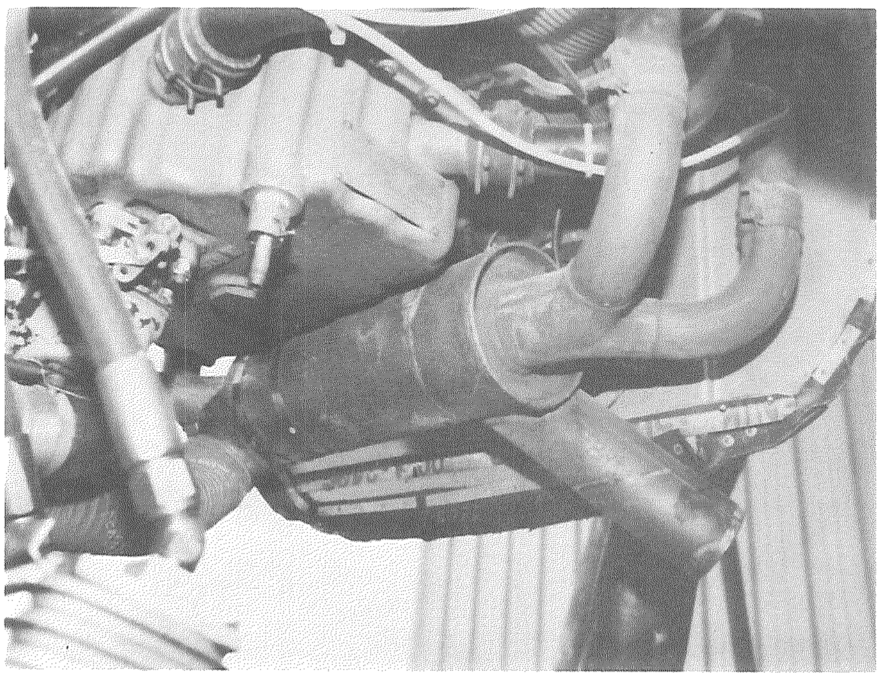
62. Lower left side oil rear engine. Oil cooler and gascolator details.



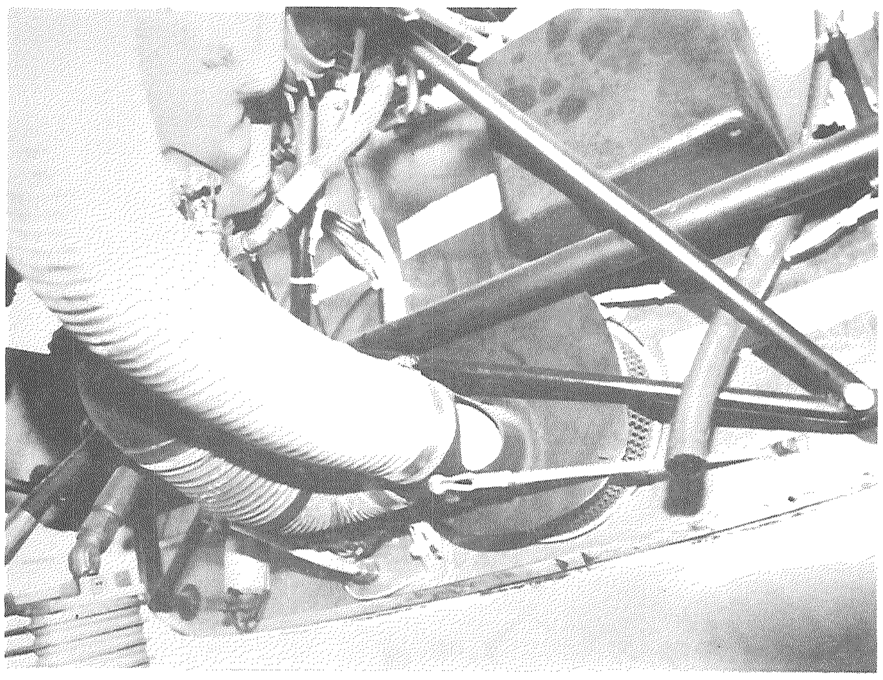
63. Right rear view of rear engine. Shows8" prop extension with fixed pitch wooden prop. Rear baffle wraps up over both rear cylinders. Note angle brace on rear baffle.



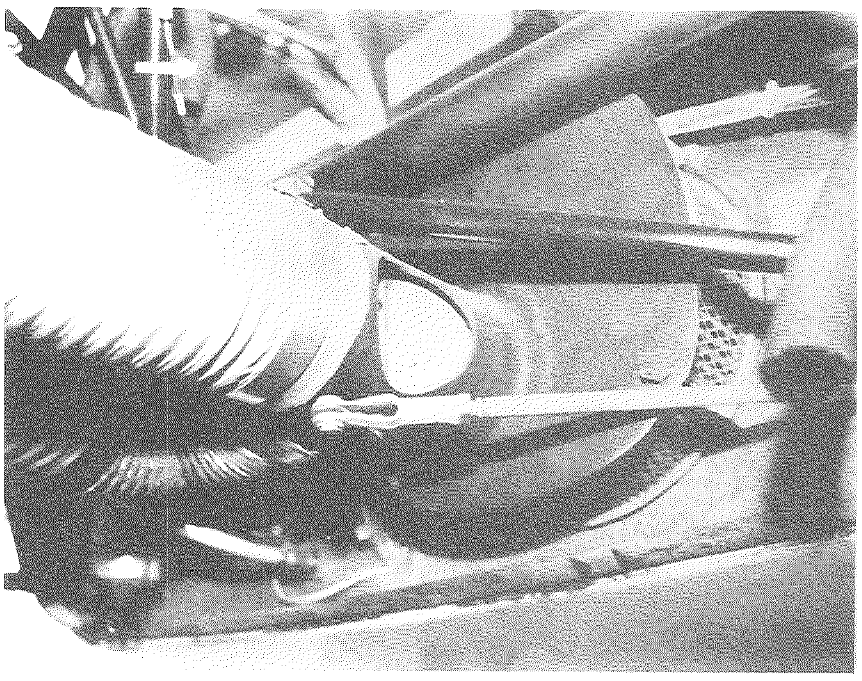
64. Exhaust system details. No heat muff is used on the rear engine.



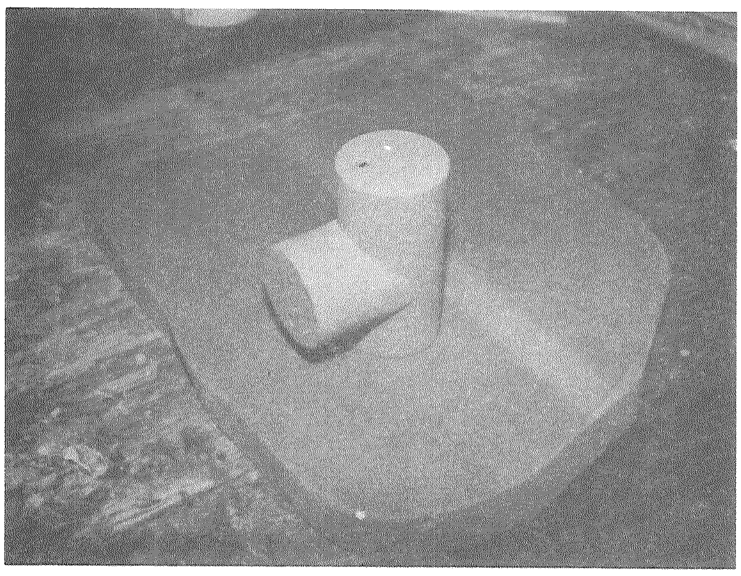
65. Carb heat "scoop" can be seen on left of muffler.



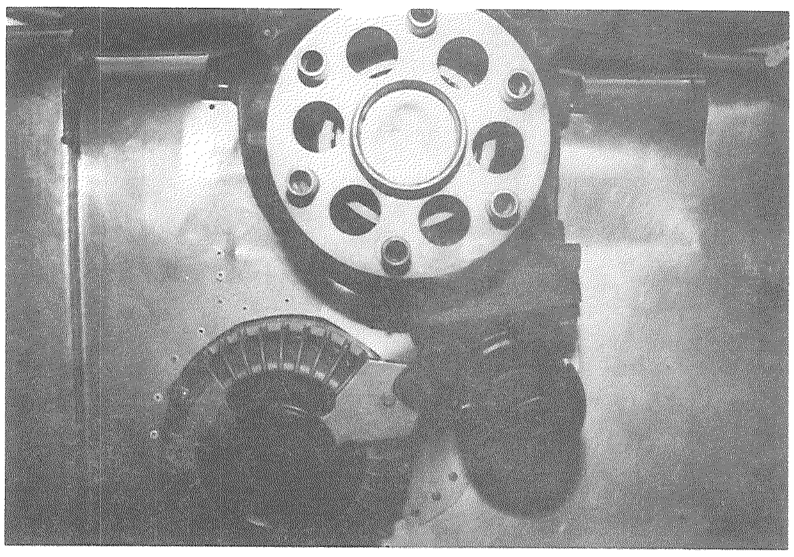
66. Home made glass carb heat valve.



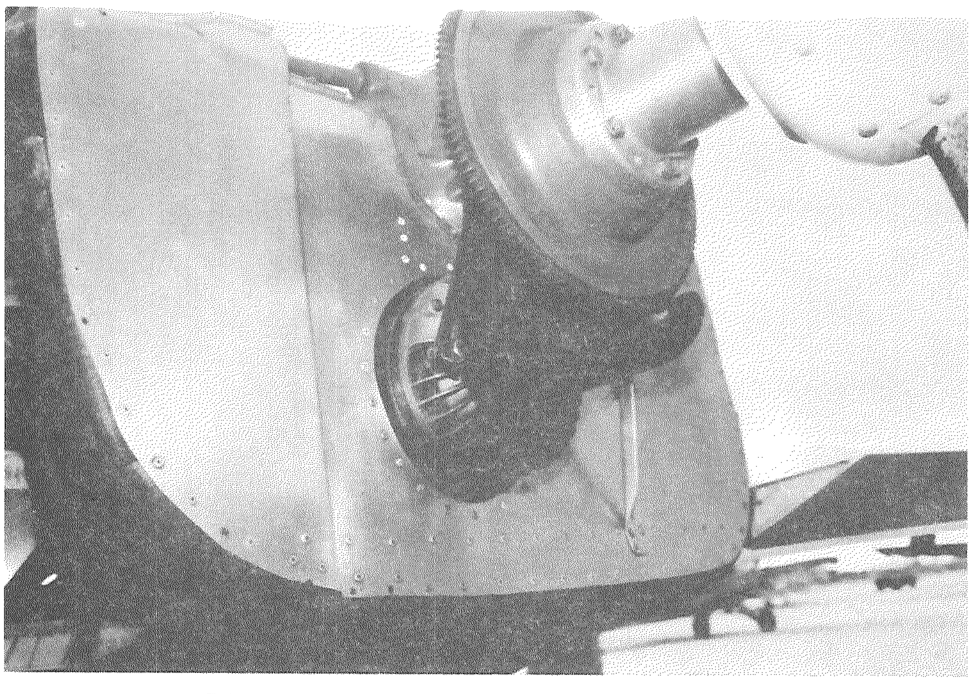
67. Details of home made carb/heat valve, not actuator for valve.



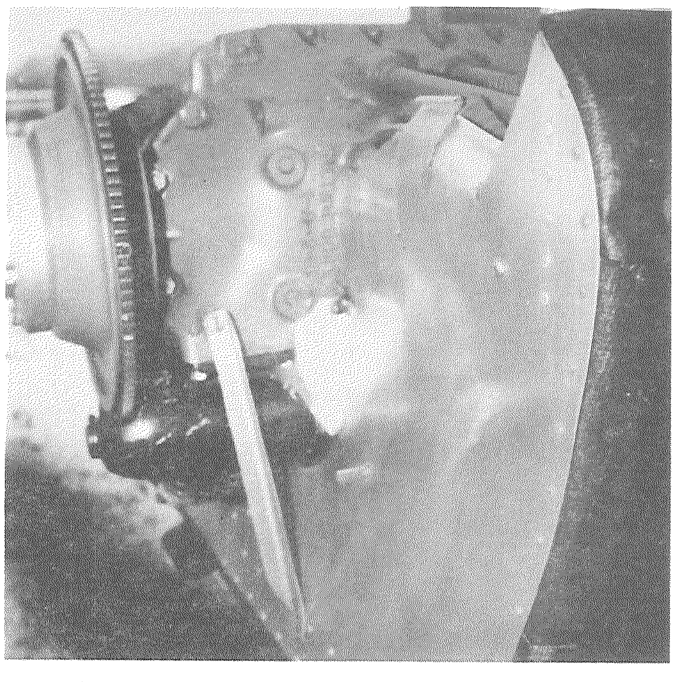
68. Foam used to make the carb heat valve.



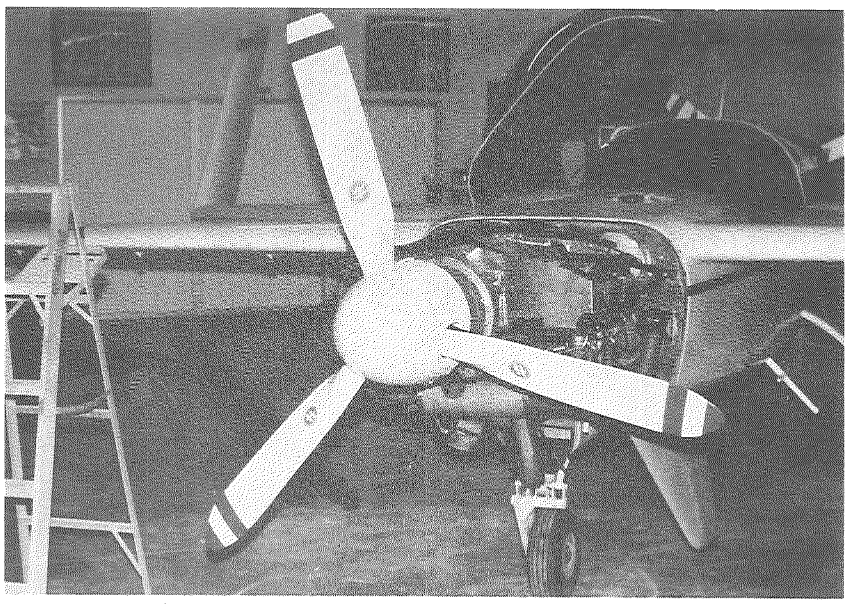
69. Rear engine crankshaft flange, starter and Chrysler type alternator.



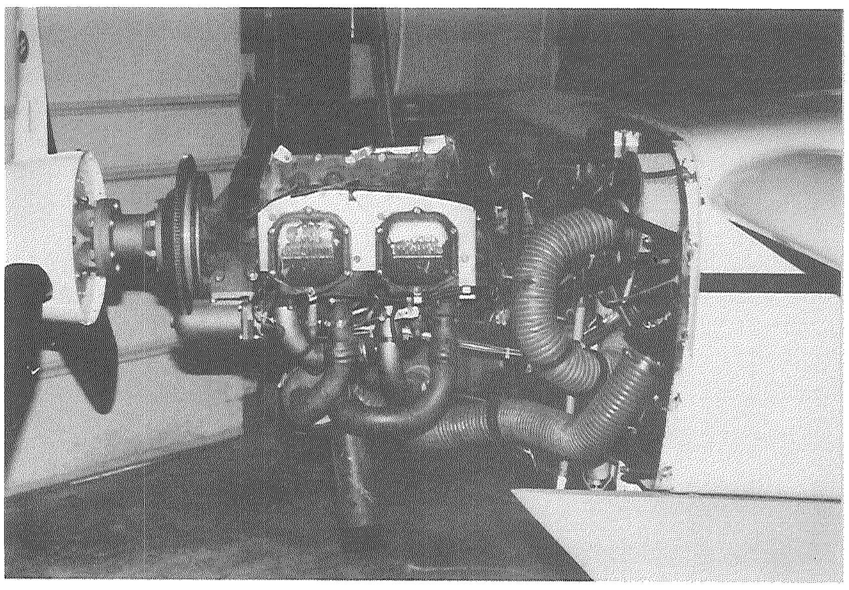
70. Rear engine aft baffle.



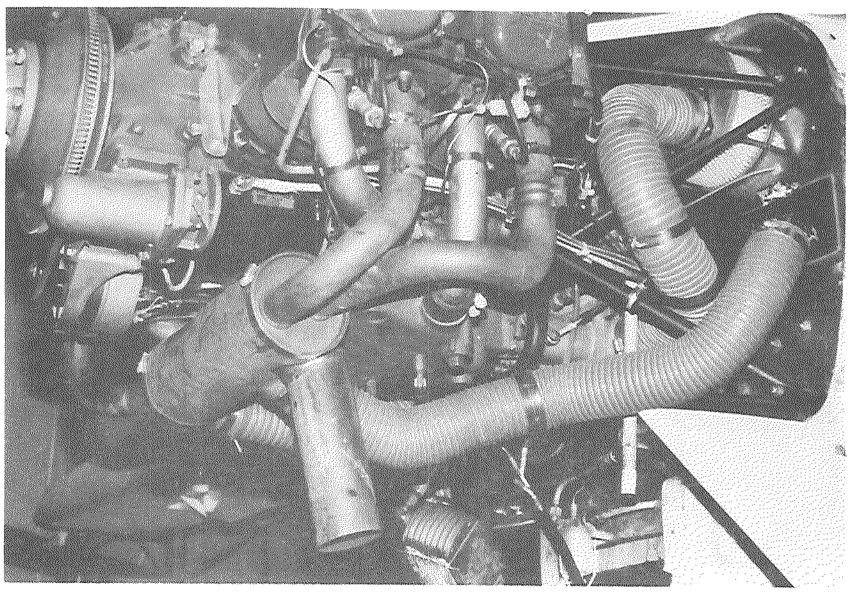
71. Rear engine aft baffle with brace to prevent aft baffle blowing aft in the cowling.



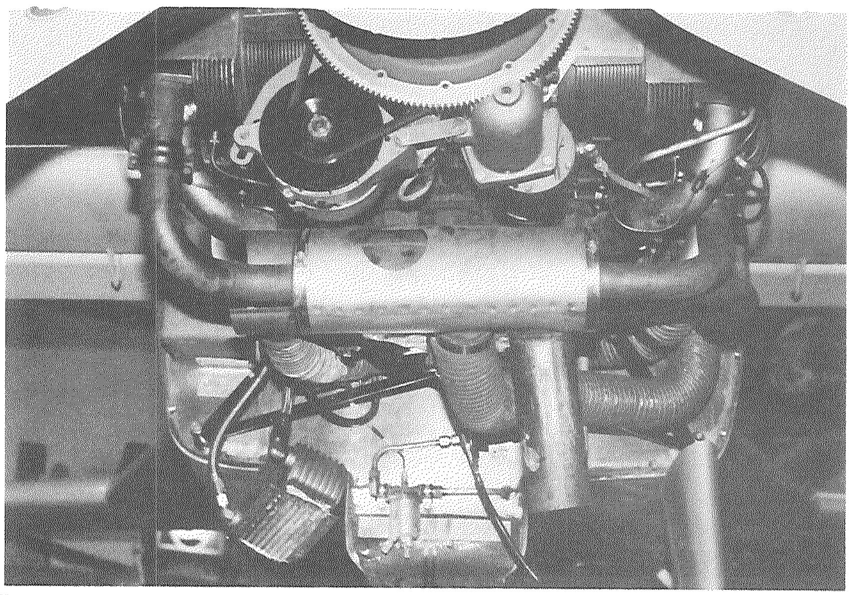
72. Burt's Defiant, N78RA front engine, showing a Hoffmann 3 blade, constant speed, feathering prop, during installation for testing.



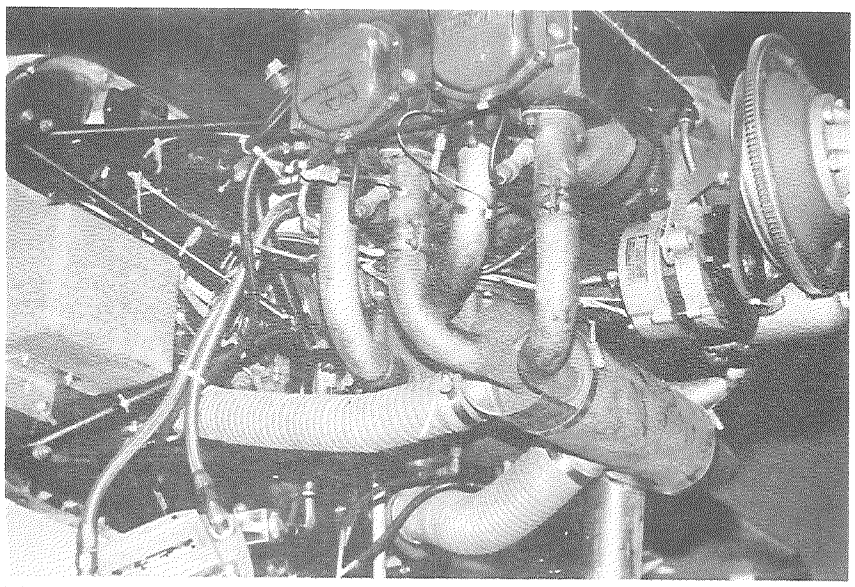
73. Left side view of N78RA - front engine. Carb air filter is mounted top left of firewall. The lower hose goes to a cabin heat on/off valve.



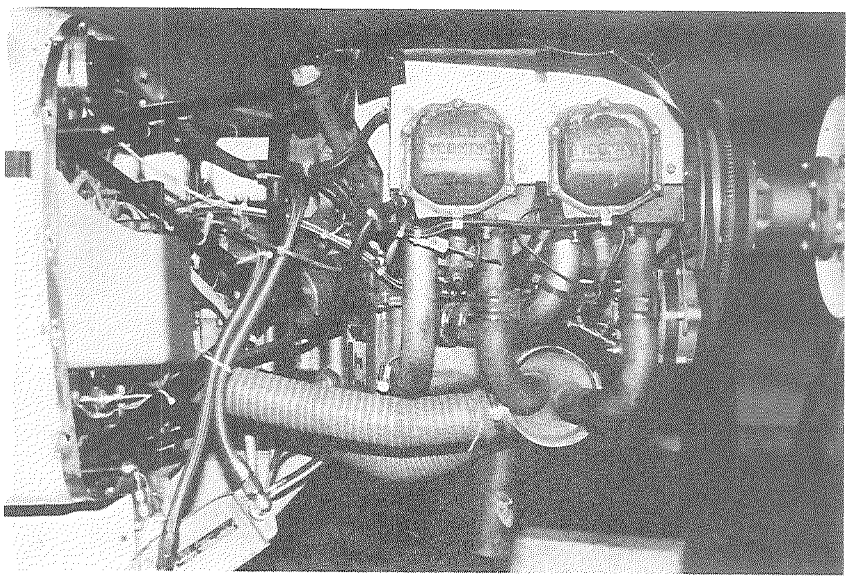
74. Lower left view of front engine shows cabin heater, hose and firewall valve. This engine has a horizontal mounted carburetor - NOT any advantage on a Defiant front engine. Vertical white tube, near rudder, is engine breather.



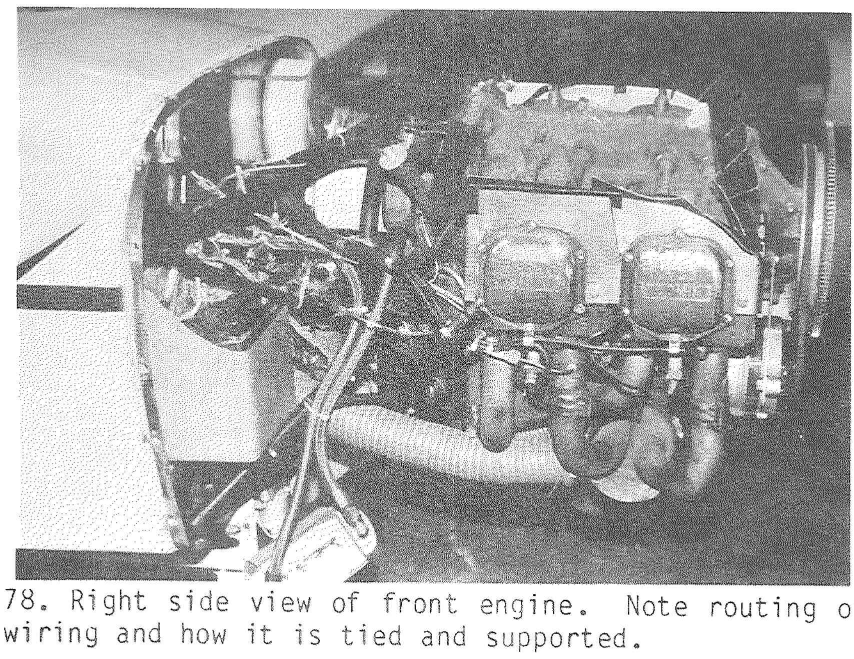
75. Front engine, lower frontal view. Exhaust system is from a Beech Duchess. Exhaust pipe (downspout) was cut and rewelded at a more vertical position to facilitate cowling installation.



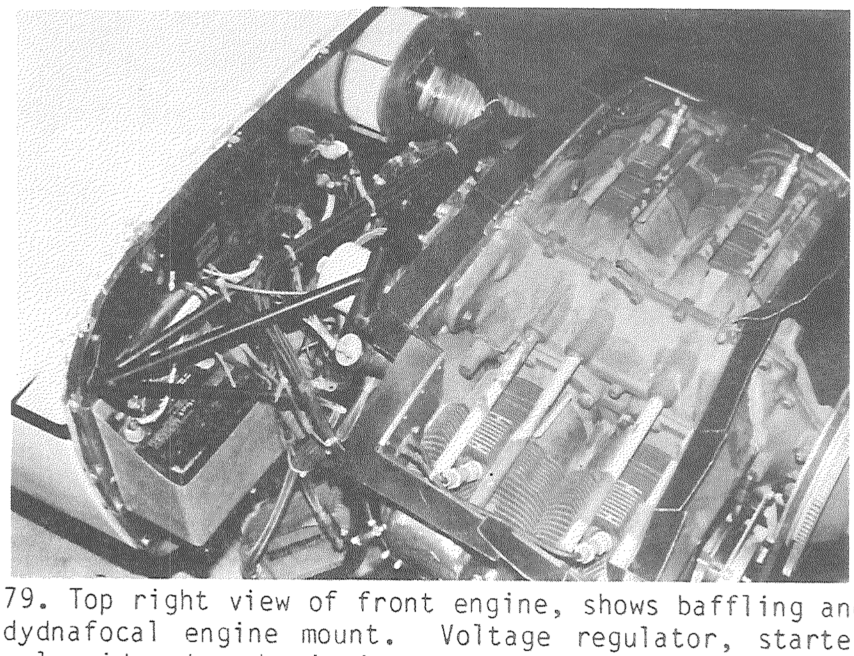
76. Lower front view, front engine, shows carburetor heater and hose to carb. Battery box is on right side of front firewall. Oil cooler is hanging on oil lines and mounts on inside of lower front cowl.



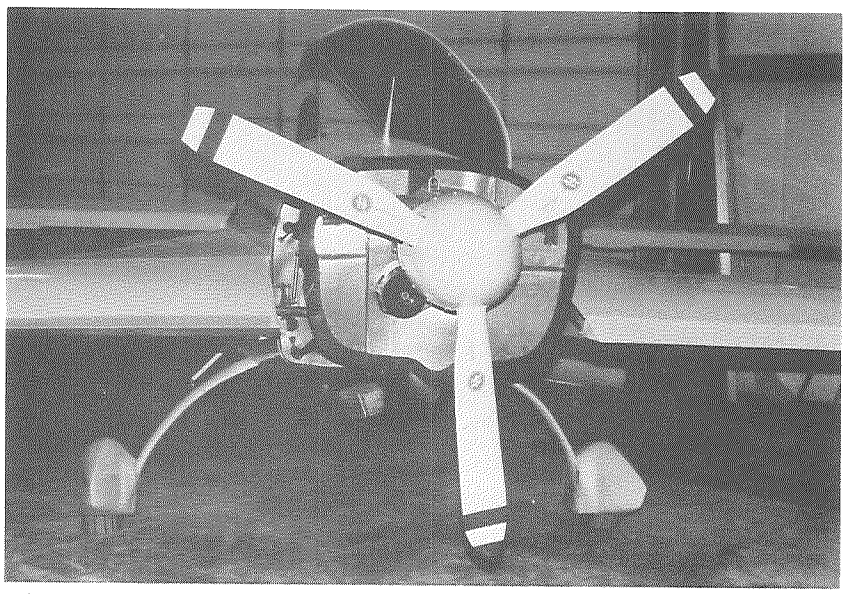
77. Right side of front engine - dynafocal mount was cut, fitted and tack welded in place on the airplane.



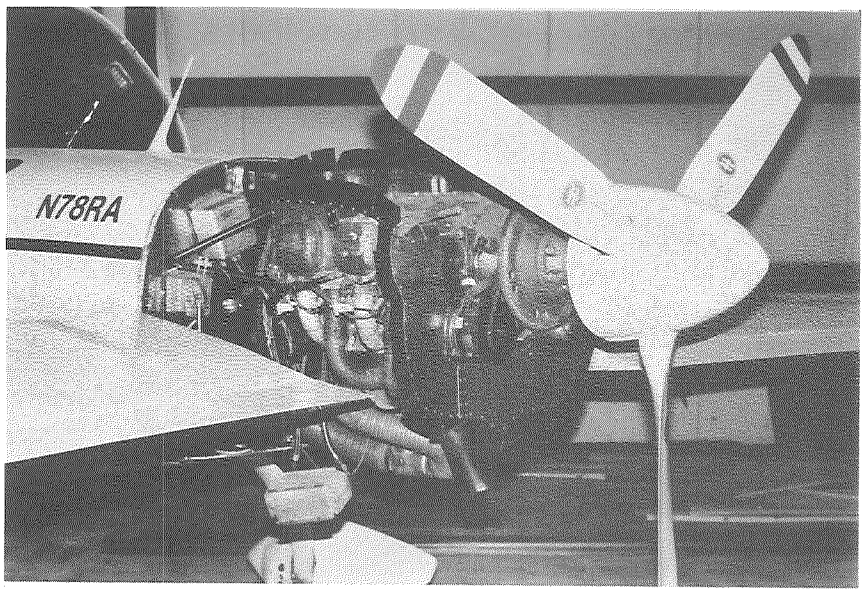
78. Right side view of front engine. Note routing of wiring and how it is tied and supported.



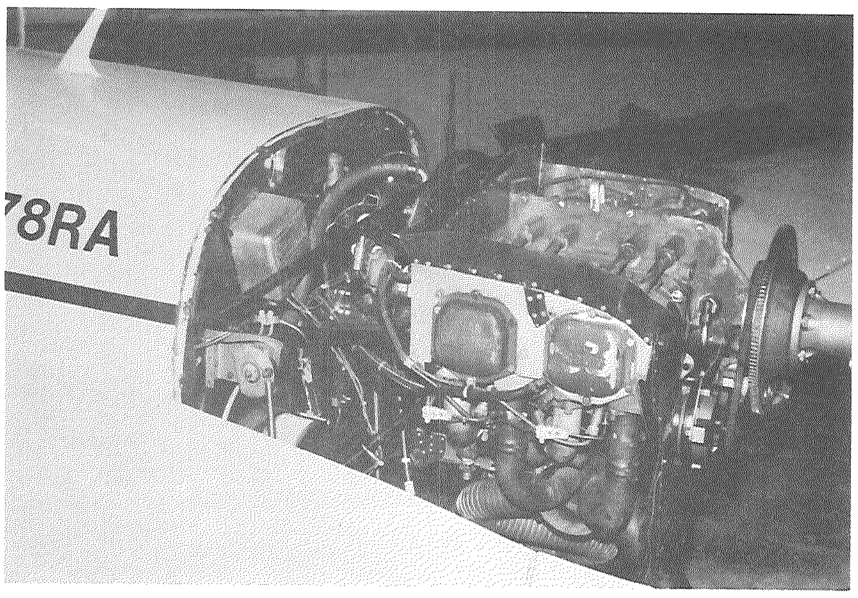
79. Top right view of front engine, shows baffling and dydnafocal engine mount. Voltage regulator, starter solenoid and carb air intake filter are mounted on the upper front firewall.



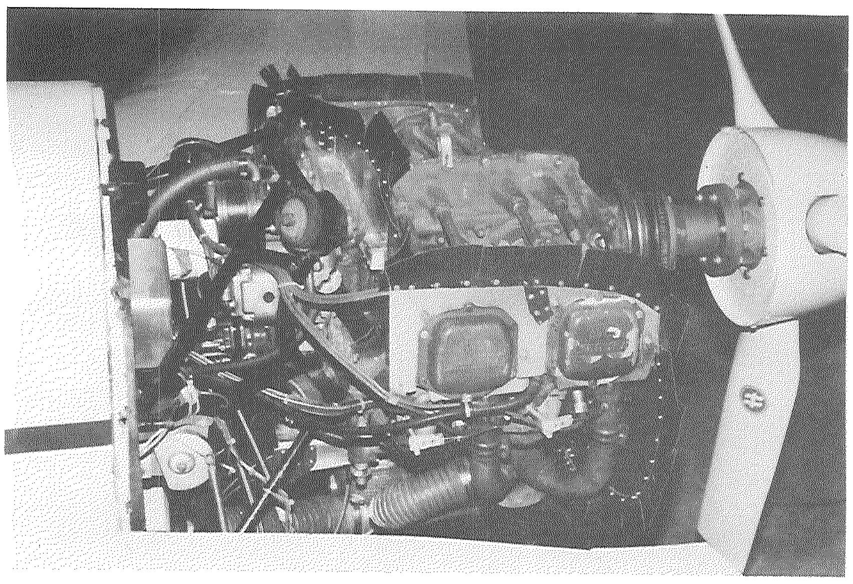
80. Burt's Defiant, N78RA, rear engine, again showing 3 blade constant speed feathering prop. Aft baffle with alternator can also be seen.



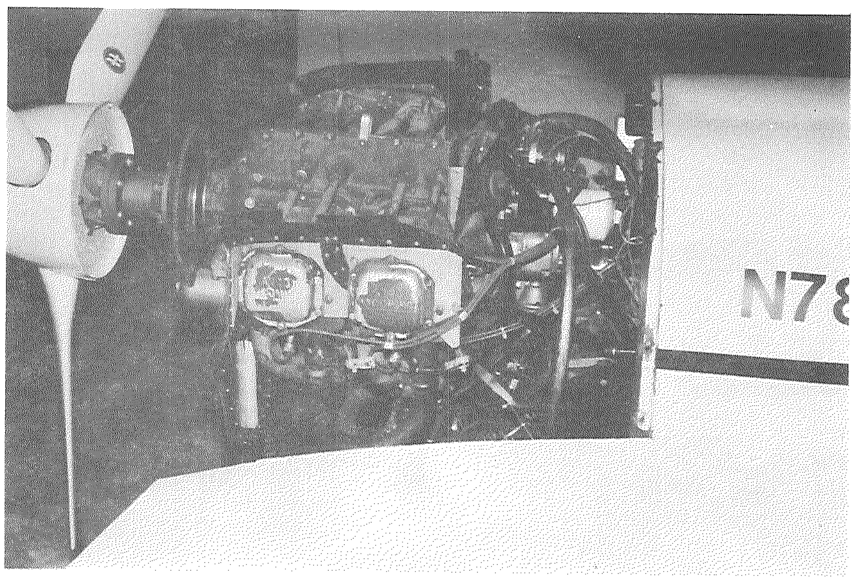
81. Left rear view shows wingtip strobe lights power supply on the top left corner, with a Century 1, wing leveller auto pilot servo mounted below it.



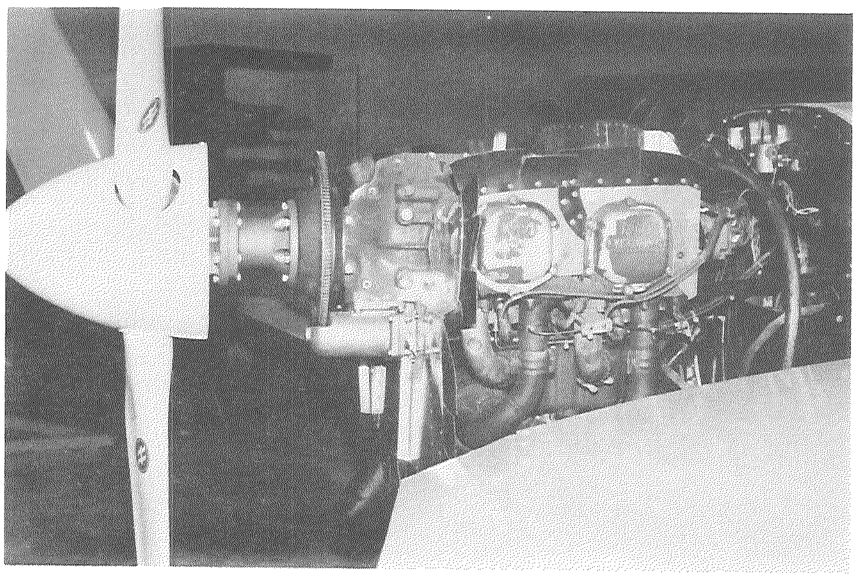
82. Left side/top view again shows auto pilot servo, strobe light power supply, voltage regulator and starter solenoid. The large hose connects the vacuum pump to a fitting on the firewall.



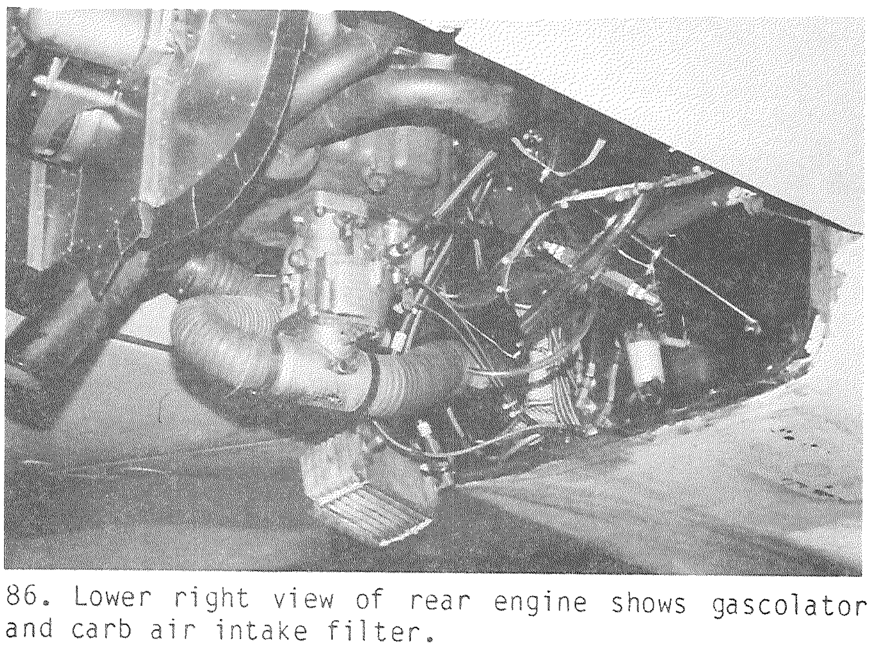
83. Left side view shows dynafocal mount, which was fabricated in position on the airplane. A 4" prop extension is used on Burt's Defiant.



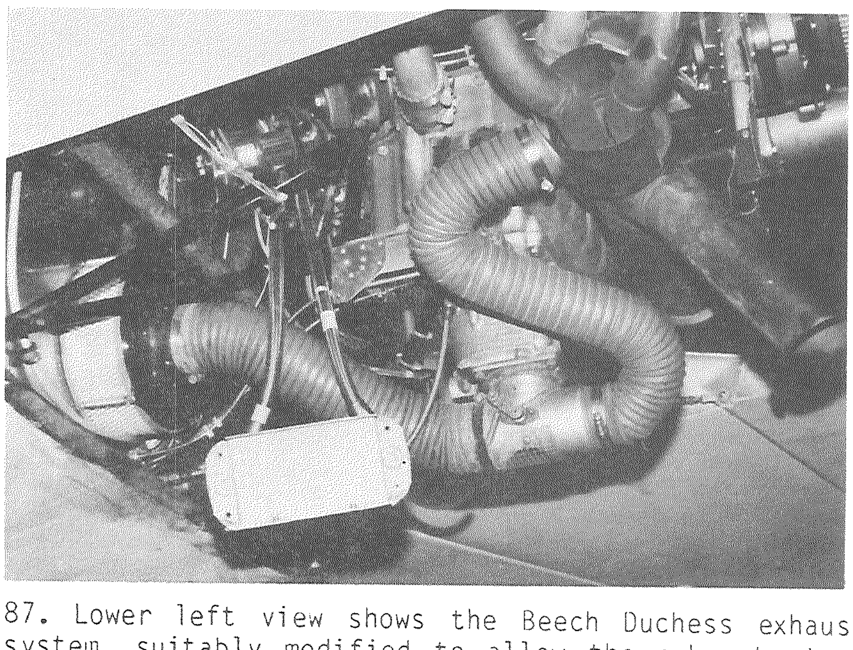
84. Top right side view, shows engine breather hose and battery mounted on the right lower side of firewall.



85. Right side view. This engine is a Lycoming 0-360-A1A, 180 hp, which used an updraft carburetor.



86. Lower right view of rear engine shows gascolator and carb air intake filter.



87. Lower left view shows the Beech Duchess exhaust system, suitably modified to allow the exhaust stack to point down and aft. Carb heat setup is the same as the front engine.